ACTA PHYTOGEOGRAPHICA SUECICA 72
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Ejvind Rosén

Vegetation development and sheep grazing in limestone grasslands of south Öland, Sweden

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Almqvist & Wiksell International, Stockholm
UPPSALA 1982

Suggested citation: Rosén, E. 1982. *Vegetation development and sheep grazing in limestone grasslands of south Öland, Sweden.* Acta phytogeogr. Suec. 72. Uppsala. 104 pp.

ISBN 91-7210-072-9 (paperback)
ISBN 91-7210-472-4 (cloth)
ISSN 0084-5914

Doctoral thesis at Uppsala University 1982.

Colour plates printed with grants from
the Axel and Margaret Ax:son Johnson Foundation.

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Svenska Växtgeografiska Sällskapet
Box 559, S–751 22 Uppsala

Editor: Erik Sjögren
Technical editor: Gunnel Sjörs

Phototypesetting by
Textgruppen i Uppsala AB
Printed in Sweden 1982 by
Borgströms Tryckeri AB, Motala

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Abstract

Rosén, E. 1982. *Vegetation development and sheep grazing in limestone grasslands of south Öland, Sweden.* — Acta phytogeogr. Suec. 72, Uppsala. 104 pp.

Changes in vegetation composition and above-ground production (standing crop) were studied in relation to grazing by cattle and sheep, and climatic and cultural influences, on dry grasslands on the island of Öland in the Baltic. In the Stora Alvaret the *Avenetum* and *Festucetum* associations were preferentially grazed.

Avenetum: (ungrazed) crop 3200 kg/ha; metabolizable energy content 2.2 Mcal/kg; (grazed) crop 1920 kg/ha; 2.3 Mcal/kg. *Festucetum:* (ungrazed) crop 1400 kg/ha; 1.8 Mcal/kg; (grazed) crop 1470 kg/ha. — Grazing (or cutting) was found to suppress graminids and dwarf shrubs; more or less prostrate herbids and acrocarpous mosses increased.

In permanent plots records were made for 11 years; fluctuations were most pronounced for *Festuca ovina*, due to climatic variations. NPK-fertilization in *Avenetum* resulted in about 200 % higher production than in control plots; graminids increased (*Festuca ovina* most); dwarf shrubs were suppressed. Monthly harvests (*Avenetum*) May—October: two maxima were found for graminids and dwarf shrubs, but one for herbids. Production was 2480 kg/ha (160 days).

Juniperus communis increased in ungrazed *Avenetum*, forming a scrub. Permanent control plot: cover of juniper stand increased 45 % in 10 years; young shrubs increasing most. Permanent test plot (cleared): standing crop for junipers 3248 kg/ha (dry weight); mean age 49 years; two peaks in age distribution. Numerous seedlings established in the cleared plot, but due to ceased grazing and gradually increasing sward, new seedlings became less frequent. Distribution maps (5-year intervals) are given. Due to snow drifts junipers gather, on average, about 50 % more snow than a cleared area. Colonization of needle-covered areas under cut junipers needed 5—7 years to develop 75—100 % plant cover.

Grazing combined with clearings is needed to maintain a high species diversity. In previously ungrazed average alvar (grazed for 180 days) a suitable stocking rate per hectare was found to be 0.9 sheep equivalents (the combination 1 ewe and 1.3 lambs) or 0.4 heifers, but with continuous grazing only 0.7 sheep equivalents or 0.3 heifers. Mixed grazing in a rotational system is recommended. Vegetation conservation aspects are discussed.

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Key-words: dynamics, fertilization experiment, juniper growth, metabolizable energy content, seasonal variation, stocking rate.

1 Introduction

On the island of Öland, in the Baltic, large-scale sheep grazing was started in the late 1950's, mainly on the so-called "Stora Alvaret", a limestone grassland area in the southern part of the island. After some years of heavy exploitation it became obvious that large areas of the Alvar were being overgrazed. Erosion occurred in several places.

The use of the Alvar attracted public debate. Land-owners refused to risk devastation of their land by renting it out to sheep farming companies. A number of Nature Reserves in the Alvar were suggested, but still have not been legalised.

In August 1967 an interimistic protection order for 3 years (according to the § 11 of the Nature Conservation law) was set up by the County Government in Kalmar, to prevent further exploitation of alvar grasslands not already being used for sheep grazing and to assure unchanged areas for future Nature Reserves. The order was later prolonged another 3 years until June 30, 1973.

Records of regional changes of vegetation due to grazing were started in 1965 by Dr. Erik Sjögren, Institute of Ecological Botany, Uppsala University.

In 1969 the Swedish National Protection Board in cooperation with the Institute of Ecological Botany, Uppsala, started an investigation in the Alvar. The present work is part of that project.

The main subjects to be investigated in the project called "Samband vegetation-betning på Ölands Stora Alvar" (Relations between vegetation and grazing on the Stora Alvaret of Öland) were: (1) relations between grazing and vegetation in various plant communities, (2) estimations of standing crop available for grazing, (3) recommendation of figures for a balanced stocking rate, and (4) continued regional surveys of changes of vegetation due to grazing (mainly sheep grazing).

The present report concerns: standing crop estimations; comparisons between sheep grazed and ungrazed areas (or weakly cattle grazed areas); and the overgrowing process, mostly by *Juniperus communis*.

Yearly records were made of taxa, and harvests were taken of permanent plots in various parts of the Alvar, also considering physiognomy of vegetation. Junipers were specially studied in one area. Sites of investigation and other places referred to are presented in Fig. 1. The project was planned to run over a period of four years. Meanwhile, new interesting aspects of more applied character came to be investigated.

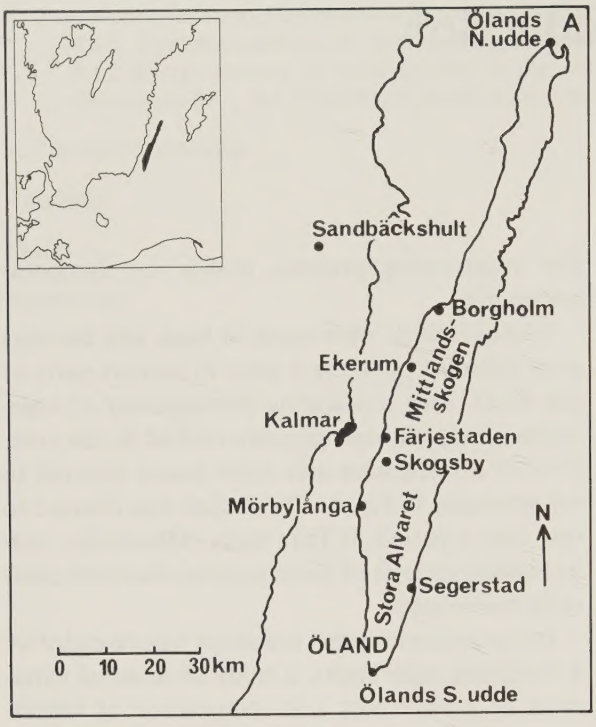
In the present context the scope was extended by a fertilizing experiment, a study of seasonal variations of productivity and composition of vegetation, analyses of digestibility and energy content analyses of the herbage, as well as winter ecological aspects, mainly snow cover.

The Uppsala University Ecological Station at Ölands Skogsby was used as a base during field investigations. The project was prolonged to 1974, when a summarized final report was presented (Rosén & Sjögren 1974).

As no further prolongation was possible, field investigations on a smaller scale were maintained by private resources and interests. Realizing the importance of long-term records in permanent plots, such registrations have been carried out until 1981.

Within the estimations of the production of the Alvar the term *standing crop* has been used as a synonym of above-ground biomass, available at a certain time. Standing crop has been divided into living crop and dead crop (necromass). Dead parts were attached. When standing crop from various harvests during the season was combined the term *total standing crop* was used.

Grazing intensity has been used to indicate the influence of both time and number of animals in relation to the area. The term *stocking rate* indicates the number of animals per hectare. For impact by cutting, grazing, and subsequent effects



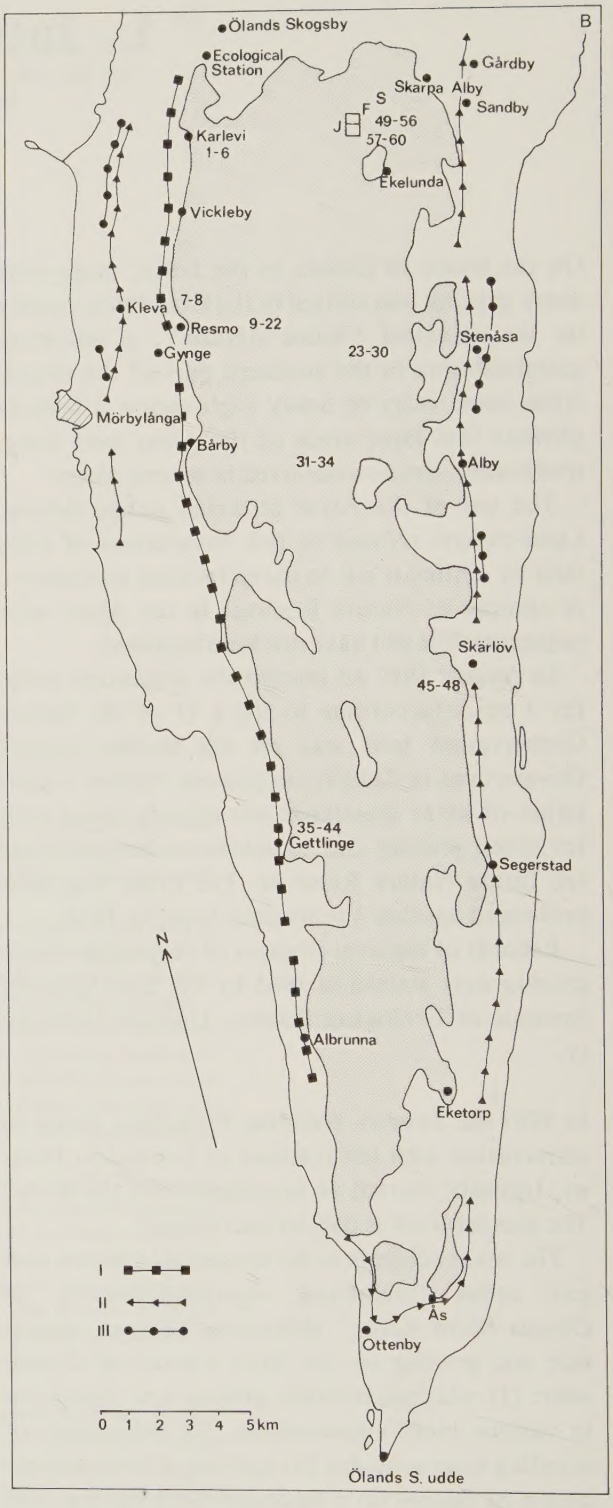


Fig. 1. Map (A) shows the location of Öland in the Baltic, and meteorological stations (or other places) referred to in the text. Map (B) shows the Stora Alvaret (shaded) and sites where permanent sample plots were established (1—60). Geological features are shown as well, I—III (I = Västra landborgen — bedrock escarpment, II = Ancylus beach ridge, III = Litorina beach ridge), J = permanent plots with junipers, F = fertilization experiment and S = seasonal monthly harvests.

the term *wear* has been used.

The terms *Stora Alvaret* and the *Alvar* have generally been used as synonyms for the area of investigation on Öland; the term *alvar* is only used as an adjective, in connection with vegetation found on other alvar areas on the island or elsewhere.

The terms *Festucetum* and *Avenetum* have been frequently used and are explained in Chapter 2.

Some names in Swedish found on the maps are: Mittlandsskogen, meaning the central large forest on the island, and Ölands N. udde, meaning the North cape of Öland. Correspondingly, Ölands S. udde refers to the southern cape.

Nomenclature of vascular plants is generally according to Lid (1974), subspecies and varieties to Sterner (1938). Lichen names follow Poelt (1969), Poelt & Vězda (1977) and Krog et al. (1980). Mosses (musci) are according to Nyholm (1954—69) and (hepaticae) to Arnell (1956). The nomenclature of plant communities follows Albertson (1950). The cover degree scale by Hult-Sernander-Du Rietz has been used for the cover records (see 3.1.1).

Taxonomic accuracy was maintained as far as possible. However, several taxa are difficult to identify as juveniles, or when they are either heavily grazed or dried out; additionally several taxa are considered as critical. For these not fully identified taxa the suffixes sp. or spp. have been used.

The following taxa may be included in these groups of sp. and spp. — *Cerastium* spp. (*C. semidecandrum, C. glutinosum, C. subtetrandrum*, and *C. pumilum*). —*Potentilla* spp. (*P. arenaria, P. tabernaemontani, P. argentea, P. cranzii*, and *P. cinerea*). — *Polygala* spp. (*P. comosa, P. vulgaris*, and *P. amarella*). — *Viola* sp. (*V. canina, V. hirta*, and *V. pumila*, and also hybrids). —*Taraxacum* sp. or spp. (several groups, mostly *Erythrosperma*). — *Euphrasia* sp. or spp. (most frequently species of the *E. stricta*-group). — *Orchis* sp. (mostly *O. mascula*, but *Dactylorhiza incarnata* and *D. sambucina* are also found). — *Cirsium* sp. (*C. acaule, C. vulgare*, and *C. arvense*). — *Hieracium* spp. (several groups, *Dichotomum, Florentinum*, and *Pilosella*). — *Rosa* sp. (*R. canina, R. villosa* ssp. *mollis, R. dumalis*, and *R. rubiginosa*).

In most of the *Festucetum*-plots *Agrostis stolonifera* includes *A. gigantea*, as these species are very difficult to differentiate in young stages. In some cases *Carex ericetorum* includes *C. caryophyllea* for the same reason. In addition, this means that the number of taxa recorded in some plots may be lower than in reality.

All photos were taken by the author, except for those with other credits.

All recorded and collected material within this investigation is kept at the Institute of Ecological Botany, Uppsala.

1.1 Cultural history

The influence of man on Öland has a long and varied history. One of the oldest settlements found is on a beach ridge close to the Stora Alvaret, near the village of Alby on the SE side of the island. This Stone-Age settlement has been dated to c. 5000 B.C. Archaeological investigations have shown that the inhabitants were fishermen and hunters, mainly eating seal and fish, but also bear, wild boar, moose, and other wild animals (Hagberg 1974 p. 23; E.S. Königsson, Lepiksaar & Königsson 1971 pp. 34 ff.).

Findings of sharpened stone-axes show that people who cleared and cultivated land lived here about 3000—2500 years B.C. (Hagberg 1974 p. 25). The area was sparsely populated during the earlier Stone-Age and also during the later Stone-Age (3000—1500 B.C.) judging from the number of settlements and gravefields found. Findings indicate that cultivation and cattle-management had developed at that time (Nelson 1955 p. 44).

The Bronze-Age lasted about 1000 years. Most of the findings are from the period 800—500 B.C. The big cairns along the coast and on the gravel deposits on the Stora Alvaret are from this period. Many finds also indicate a strong societal organization with wide contacts abroad. However, our knowledge of this period is still very limited and house foundations have yet to be found (Hagberg 1974 p. 26).

Around 500 B.C. a strong climatic change took place, resulting in cold and wet summers. The archaeologist Mårten Stenberger suggests that people then had to arrange more permanent settlements with good shelters for themselves and their animals during the winter. At that time the migrations of the Celtic people probably severed the Ölandic trade from the metal-producing countries of Middle Europe. The period between 400—150 B.C. in the history of Öland and Scandinavia must be characterized as one of poverty (Nelson 1955 pp. 45 ff.).

Later, when the Nordic people had reached trading agreements with the Celts, rapid changes took place. Öland has numerous finds from that era and up to year 0 (the Celtic Iron Age). During the following period, 0—400 A.D. (the Roman Iron Age), Öland was very prosperous.

From 400—550 A.D. the island was even richer but this was also a time of disaster (Nelson 1955 pp. 45 ff.). Hagberg (1974 pp. 27 ff.) also considers the period from 150 B.C.—500 A.D. (older Iron Age) as a prosperous time for Öland. At that time there were more permanent settlements as evidenced by large gravefields with well-constructed tombs. Findings with Celtic and Roman design are found, as well as coins from southeastern Europe. Stenberger considered that the welfare of Öland during the older Iron Age mainly was based on cattle management, referring to the pattern of buildings with cattle lanes and adjacent paddocks which is characteristic of that time. Rye was also cultivated (op. cit. p. 31).

The first difficult period for the Stora Alvaret started in the first centuries A.D., when the impact of man increased on the landscape. People even settled in the Stora Alvaret. More than 40 house foundations have been found from that time, most frequently located on gravelly deposits (Enckell et al. pp. 336 ff.), each probably representing a farm. These people created for the first time the open shape of the Alvar as we know it (Königsson 1968 pp. 161 ff., 1974 p. 142). In addition to their grazing animals, the settlers also used small arable fields. Hagberg (1974 p. 31) is of the opinion that land was utilized too intensively during the first centuries A.D., which resulted in overgrazing and erosion in outlying land such as the Alvar.

During the 4th and 5th centuries migrations in Europe that severed trade connections and climatic changes, together with over-utilization of the land, were probably components in the resulting depression. The settlers on the Alvar were the first that had to give up. Possible reasons for that recession are discussed in ecological terms and societal systems by Enckell et al. (1979 pp. 328 ff.). Settlements on Öland became subjected to plundering expeditions from overseas. The inhabitants then started to build ring-forts for shelter. During the 4th and 5th centuries, 16 such forts were constructed. They were strategically located, mainly in the central part of the island, but some also on the coast. A detailed archaeological investigation has been made of the ring-fort at Eketorp, in the southern part of the Alvar, which was used during three periods from the 4th to the 14th century. The ring-forts are all found at sites where water was available. Some of them might have had a religious connection. Food at that time included mutton and beef, and on religious occasions, horsemeat (Hagberg 1974 pp. 31 ff.).

Around 500 A.D. the settlers had left the Alvar and a period of recovery and overgrowing of the vegetation started. This was partially stopped at the end of the Viking Age but a new phase of overgrowing took place during the Middle Ages (Königsson 1974 p. 142).

Most of the large gravefields on the beach ridges, and on the klint in the southern part of the island originate from the younger Iron Age, especially the Viking period. Nevertheless, it is not clear where the people lived at that time (Hagberg 1974 pp. 39 ff.).

In *History of the Nordic People* written in the mid 16th century, Olaus Magnus mentions big herds of small but strong horses on Öland. He also reports an overabundance of cattle, horses, fish, etc., much of which was sold abroad. Verification of these important exports from Öland is found in archives from Danzig, reporting, for example, that in 1474—76, a total of 30 ships arrived from Öland with oxen, horses, butter, cheese, lambskins, etc. (Palm 1974 pp. 8 ff.).

Palm (1974 p. 14) considers that agriculture on Öland received a very severe set-back when the Swedish king Johan III declared Öland to be a private hunting ground ("djurgårdsinrättning"). The farmers were only allowed to own cultivated land, while forests and all outlying land, including the Alvar, became crown common land, where only grazing was allowed.

The people were not allowed, for example, to hunt or to cut living trees for firewood. Very severe punishment followed violation of the rules. Nevertheless, firewood was frequently stolen (Nelson 1955 p. 50). Wild boars and deer caused considerable damage to crops but the farmers could do nothing but try to frighten them away.

Maps from later parts of the 17th century show fairly small areas of arable land, but large areas of outlying land which became gradually more and more open by grazing (Palm 1974 p. 8).

In the description of his travels during 1741, Linnaeus wrote that "The Alvar itself lies like a desert or a sterile common land for the cattle" (Linnaeus 1745 p. 60). Linnaeus also tells us that the Alvar at that time stretched from Ottenby in the south to Borgholm in the north. It was not divided by fences between villages or parishes (op. cit. p. 97).

Königsson (1974 p. 142) claims that a new expansion started on the Alvar during the 17th and 18th centuries and culminated in the 19th century. In my opinion, the damage to cultivated land caused by the wild animals probably forced the farmers to increasingly base their existence on grazing animals. Consequently, the pressure on the outlying land increased, which resulted in an opening up of the landscape. This explanation concurs with facts given by Palm and Königsson.

The hunting ground declaration remained in force until 1801 and for more than two centuries the agriculture had been restrictively influenced and the people impoverished. Larger woodland areas had also been cut down and not replanted (Nelson 1955 p. 50).

In the 18th century the agriculture turned towards a larger production of cereals. Windmills were built. In 1710 a plague decreased the population by about one-third to 10,000 inhabitants. After a rapid growth the population reached about 22,000 persons at the end of the century (Palm 1974 p. 18).

In the early 19th century the conditions for agriculture were changed by the enclosure process ("enskifte" and "laga skifte") and the outlying crown common land was divided among the villages. The row-village form originating from the Middle Ages did not change much as a result of the enclosure process for several reasons. However, many new settlements were established outside the villages (Göransson 1969 pp. 69 ff.).

Land reclamation was one of the major tasks of the 19th century (cf. Ekstam & Sjögren 1973 p. 127). Cultivation increased and by mid-century there was a large export of cereals. At the same time the gap between poor and rich people became more accentuated (Palm 1974 p. 19).

In the beginning of the 19th century farmers started to enclose their private fields and grazing lots with stone walls, and this also took place on the Alvar (Göransson 1969 p. 78). In many places, however, the Alvar was retained as common land for the village. Sheep and cattle

were tended. The grazing intensity was regulated annually by the village council.

It became increasingly difficult to find firewood, and consequently all kinds of shrubs and dung were collected on the Alvar as late as in the 1930's (Johansson & Larsson 1978 p. 42). This clearing created an almost shrubless alvar area.

In 1867—68 when the population had further increased to 38,000 there were serious crop failures and it became obvious that the island was overpopulated. A wave of emigration started, in which as many as 12,957 young people emigrated to N America during 1881—1910. Öland lost more than one-fourth of its population in 30 years. In the 20th century the advent of new methods improved the conditions for agriculture, and some industries also became established.

After 1935 a new decrease of the population was created by rationalizations in agriculture and population concentrations. Another fourth of the population left the island during the period up to 1972, when a bridge to the mainland was opened (Palm 1974 p. 22). The present trend is for people to move back to Öland again.

Changes in population and agricultural methods over the last century have clearly influenced the use of the Alvar. Such changes must be taken into consideration for the understanding of vegetational changes in the landscape. Further discussions on this subject are given below.

1.2 Bedrock geology and quaternary deposits

As on the other large islands of the Baltic the surficial bedrock on Öland mainly consists of limestones. There is a narrow strip of non-calcareous alum shales and sandstones in the west dating back about 560 million years. The limestones belong to the Ordovician sedimentation (Regnell 1948; Martinsson 1974 p. 119). The sedimentation occurred in a basin which now has its central parts far to the southeast, and the sediments have pressed the bottom of the basin downwards forming a dip in the layers from the peripheral part of the basin towards the centre.

1.2.1 Geomorphological aspects

Geomorphologically, Öland forms part of a *cuesta* landscape which characterizes the Baltic today. Escarpments directed in bow form run from the Kalmarsund area via Gotska Sandön and the northern coast of Estonia to Ladoga and parallel bows of escarpments may be found in the direction towards the southeast. The largest of these escarpments form the present coastlines of Öland and Estonia and the coastlines of Gotland and Saarema respectively (Martinsson 1958, 1974, 1980). These escarpments are thought to have been formed by river systems during the Tertiary and to have been reformed and sharpened through the activity of the repeated glaciations during the Quaternary (cf. Königsson 1980 and references there).

The escarpments along the western coast of Öland roughly constitute the border between the Ordovician limestones to the east and the Cambrian and Precambrian layers to the west. It is called Västra landborgen on the island, and forms the most pronounced morphological feature on Öland. West of this feature, a coastal plain slopes down to the shore of Kalmarsund. The plain is narrow in the southernmost parts of the island, only a few metres to a couple of hundred metres wide, and is widest close to the small town of Mörbylånga, where it reaches a few kilometres in extention. Just south of Mörbylånga the Västra landborgen reaches its highest levels, some 57 m a.s.l. East of the landborgen the surface of the island slopes down to the present shores of the Baltic proper, a gentle dip with few and very modest irregularities.

Öland is largely characterised by fissure systems in the bedrock. They are most clearly visible in areas with totally exposed bedrock, but are also found under the pattern of vegetation strips on thin soils (Fig. 2). Totally exposed bedrock is not frequent in the Alvar, but found locally.

The fissures were mostly healed with calcite, but are frequently opened by weathering in their superficial parts, being considered as karst phenomena. Also dolines and dome-like features occur, but fairly rarely (Svensson 1963; Königsson 1977). The fissures partly may be filled with an organic debris emanating from plant communities on the surface and/or by sedimented material containing, e.g., soluble calcareous material and various particles that have been transported by water (Königsson 1977). Fissure systems are of great importance for the drainage of the Alvar, but also as a link with the ground water level, e.g., by artesian wells, providing water also during extremely dry periods. Soluble calcareous material originates from superficial parts and fissures in the bedrock, but also from scarps more or less hidden in gravelly deposits (Königsson pers. comm.).

During the repeated glaciations during the Quaternary the morphology of the island became reestablished and erosive and accumulative forces were active. It is probable that the extension of the island was larger in the oldest periods, and that the Baltic flooded the island during the interglacial stages, thus affecting the deposits left on the island by the various melting continental ice sheets. The bedrock morphology may have sharpened, at least as regards the cuesta landscape. Most of these deposits have been transported away from Öland during following glaciations and at present there are no known deposits older than from the last glaciation or from the present interglacial.

When the last glaciation terminated it was assumed that the island was covered by tills and by glaciofluvial materials in places. The island was, however, soon flooded by the various substages of the Baltic, sometimes lacustrian, sometimes marine. During the Baltic

Fig. 2. Surficial fissures are characteristic of the bedrock of Öland. They are easily distinguished in karst areas with totally exposed rock, but their presence is also revealed by the pattern of vegetation strips in areas with thin soils. Water is temporarily dammed and collected between the strips in atumn and spring. *Carex flacca, Sesleria coerulea* ssp. *uliginosa* and *Potentilla fruticosa* are frequently found in this vegetation. — Alvar of Nedre Ålebäck. October 1968.

Ice Lake stage all of the island was covered by water, and thus no part has totally escaped being wave-washed, which must have affected the surficial deposits so that the finest particles were removed. During the subsequent stages—the Yoldia Sea, the Ancylus Lake, and the Litorina Sea and its successors—successively smaller parts of the island were covered by the transgressive water masses. Each of these stages however transformed the deposits more or less totally, washed away much of the fine grained material and deposited the coarser into beach ridges which form the most common landforms, although on Öland normally in very flat forms.

1.2.2 Quaternary deposits

Tills and littoral materials

It has been assumed that the till cover on southern Öland was originally very thin. The reason for this has been discussed in the literature, one opinion being that the competition of two ice lobes over southern Öland, one in the Baltic east of the island and one from the Swedish mainland, created a situation where only small amounts of glacial debris were carried into the area and then deposited there. The tills (and also very likely some glaciofluvial materials occurring in certain zones, cf. Königsson 1968 p. 49, Fig. 38, Map enclosure; Königsson 1980 Fig. 3) were then transformed into predominantly littoral materials by the Baltic wave-washing. Littoral materials constitute beach ridge system, which line up the inner parts of the island, the Stora Alvaret, roughly parallel to the length axis of the island. The beach ridges and the littoral deposits are the most frequent landforms, being Quaternary deposits on the Alvar. They have silty-sandy matrix and carry more or less rounded pebbles, sometimes in considerable quantities. The creation of the present distributional pattern of littoral deposits there happened during a period of one thousand years or slighly more, approximately 10 000—8700 B.P.

Deposits on the Stora Alvaret that do not follow the normal pattern parallel to the length axis of the island, but crossing more or less perpendicularly, have been demonstrated to be tills in the cases examined up to the present. They often follow the tectonical zones described by Stephansson (1971) and seem to have been preserved in the sheltered position in depressional parts of the zones (Königsson 1968). Tills may also still persist in more boulder-rich areas of the Stora Alvaret, but to what extent they are in primary position and to what extent the fine grained parts of the tills have escaped the wave-washing is not yet known.

In cases where tills on southern Öland have been investigated as to their textural properties, they may be described as boulder clays (more than 15% of the deposit is made up of the clay fraction) and the matrix is coarser in the west and finer in the east. The limestone content is most abundant in the east and decreases towards the west, where Västra landborgen marks the limit from which the ice could originally capture limestone debris for deposition in the ice movement direction towards the south or towards the southeast (Königsson pers. comm.).

The weathering of the deposits on the Alvar has been preliminarily studied (Königsson pers. comm.). It has been found that the lime content is decreasing and that the postglacial weathering has reached at least one and a half metres down in deposits that are that thick (very few deposits on the Stora Alvaret have a thickness exceeding one metre).

The drainage of surface waters from the Quaternary deposits follows two principal patterns; the less permeable tills mainly have a horizontal runoff, while the littoral ridges combine a percolation of the precipitation with some horizontal run-off. The cover of wind-tran-

sported material may, however, be expected to be less permeable when water-saturated and in this condition horizontal drainage may predominate.

As the gravelly deposits are comparatively poor in lime material, at least superficially, they have an acid soil reaction although their thickness often is only a few decimetres. Values between pH 5.1 and 6.9 have been reported by Rodenborg (1976 pp. 42 ff.). Similar values are given in 6.1.3 within or close to junipers, but with increased values close to the underlying bedrock.

Weathering deposits

In between gravelly deposits, the bedrock is covered by thin weathered soils, originating from the bedrock by frost action, biological activity and chemical weathering in combination, providing a basic soil reaction. Sterner (1938) separates these soils into two types: a gravel type with more or less fine material and a type called *alvarmo*, not connected to any specific grain size distribution.

In shallow basins weathered material becomes mixed with muddy material containing lime and plant detritus. When poorly drained, frost-induced movements regularily occur in these soils (alvarmo), forming polygon structures with sorted material (cf. Fig. 10), frequently found in the Alvar (cf. Hesselman 1915; Sterner 1926; Rydkvist 1960; Königsson 1968 Fig. 26).

Wind transported deposits

Wind transported material is frequently found, e.g., on top of gravelly deposits and trapped in the vegetation, often forming a layer of about 20 cm in thickness (locally more). These soils contain organic matter and minerogenic material, such as quartz and feldspar. Grain sizes are silt and fine sand, but coarser fractions may occur. In a dry stage such soils are easily eroded if overgrazed and trampled (Königsson 1968 pp. 45 ff.).

Soils of alvar pools, lakes, and fens

In depressions in the bedrock surface or in gravelly deposits (often combined with scarps) water collects, forming temporary pools or more persistent fens or lakes. The thin sediments in pools contain weathered soils, gyttjas, and marl, while the lakes and fens contain peat, lime gyttja and lake marl.

According to Enckell et al. (1979 p. 337 Table 2), karst areas cover 1%, gravelly deposits 26%, weathering deposits 54%, and fens and wet meadows 18% of the Stora Alvaret area.

1.3 Climate

Climatic conditions play an important role for plant and vegetation dynamics. A review of such conditions concerning Öland is presented below. No total description is available for the island, but some authors have discussed climatic factors in their works, e.g., Sterner (1938, 1948), Bergsten (1955), Sjögren (1961), Königsson (1968), Rodenborg (1976), Widén (1980), and Rosén (1980b).

During the summer W and SW winds predominate, bringing rain from the Atlantic ocean to the southern part of Sweden. On their way to the Baltic Sea they have to pass the southern Swedish highlands, where most of the rain falls, leaving very little for the SE coast which, together with Öland, is thus situated in the rain-shadow of the mainland.

Öland and the SE coast of Sweden receive most of their rain from the S or E, but such winds are less frequent. As the island is very low (highest altitude 57 m) rainclouds arriving with these winds often pass over Öland, the rain falling first when they reach the mainland.

1.3.1 Precipitation

The fact that Öland is situated in the rain-shadow is clearly reflected in mean values of annual precipitation from various meteorological stations on Öland. Bergsten (1955 p. 36) shows, for 1901—1930, the lowest mean values of precipitation (400—450 mm) at the very north and south ends of the island, and along the coastal areas. These parts, together with some areas on Gotland, have the lowest precipitation in southern Sweden.

The stations located in the central part of Öland show figures around 500 mm, probably due to higher altitude

Table 1. Mean yearly precipitation (mm) in two periods (1965-79 and 1969-79). Individual years are given for 1969-79. Values from three meteorological stations and the Ecological Station, Ölands Skogsby, all close to the Stora Alvaret. (Values within brackets somewhat too low; cf. explanation in the text.) Highest and lowest values are underlined for individual years.

	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	Mean 1969-79	Mean 1965-79
Olands Skogsby	449	533	326	375	414	539	328	404	(454)	472	429	(429)	(430)
Mörbylanga	545	550	350	528	481	497	314	491	475	478	505	474	486
Segerstad	528	528	429	380	458	546	322	424	459	463	534	461	471
Olands S.udde	492	491	342	406	436	536	343	425	461	428	457	438	464
Amplitude	96	59	103	153	67	49	29	87	(21)	50	105		
Mean value	504	526	362	422	447	530	327	436	(462)	460	481	(451)	(463)

Table 2. Monthly precipitation (mm) during 1968-80 and mean values for 1965-80 at the Ecological Station, Ölands Skogsby. Figures rounded off to closest integer. Figures within brackets are not included in the calculation (explanation in the text).

Year	1968	-69	-70	-71	-72	-73	-74	-75	-76	-77	-78	-79	-80	1965-80
Jan.	26	25	4	14	8	22	24	37	18	35	25	20	26	22
Febr.	19	23	2	11	15	70	28	3	1	26	41	11	14	20
Mar.	12	1	24	17	27	22	17	37	10	(11)	39	28	18	21
Apr.	7	33	52	26	35	35	7	13	36	(19)	18	43	24	27
May	59	82	37	42	40	27	18	53	57	22	5	36	11	41
June	27	3	30	38	14	36	14	5	47	31	35	46	24	25
July	68	5	95	33	54	30	99	18	35	110	52	61	67	53
Aug.	34	156	79	26	70	7	34	33	33	24	61	69	86	52
Sept.	34	29	36	30	61	78	33	70	47	(21)	110	17	44	49
Oct.	69	6	65	35	7	29	141	30	25	(33)	16	2	115	44
Nov.	63	83	93	22	32	28	81	26	10	58	32	65	34	48
Dec.	9	2	15	31	12	30	44	4	85	63	40	32	37	34
Mean	429	449	533	326	375	414	539	328	404	(454)	472	429	500	433

Table 3. Precipitation values (mm) for the main growing period (April-September) and the critical period (May-July) from the Ecological Station, Ölands Skogsby in 1968 80. (In 1977 the values are uncertain for April and September; cf. text)

Year	1968	-69	-70	-71	-72	-73	-74	-75	-76	-77	-78	-79	-80	Mean
A-S	229	309	329	195	274	213	204	191	255	(228)	280	272	256	(249)
M-J	154	91	162	113	109	93	130	76	139	163	91	143	102	120

Table 4. The main growth period separated into intervals of low, medium and high amounts of precipitation (mm) with means for April-September 1969-72. Data received from the Ecological Station, Ölands Skogsby

	Time	Days	Precip.	Precip./day
1969	12.4 - 20.5	39	110	2.8
	21.5 - 19.8	91	15	0.2
	20.8 - 30.8	11	152	13.6
	31.8 - 20.9	21	3	0.2
	21.9 - 26.9	6	27	3.9
	27.9 - 11.11	46	8	0.2
1970	1.4 - 13.5	43	84	1.9
	14.5 - 11.6	29	6	0.2
	12.6 - 13.6	2	18	8.9
	14.6 - 29.6	16	5	0.3
	30.6 - 14.7	15	16	1.1
	15.7 - 17.7	2	56	27.8
	18.7 - 19.8	33	109	3.3
	20.8 - 10.9	22	1	0.05
	11.9 - 31.10	51	101	2.0
1971	4.4 - 30.4	27	26	1.0
	1.5 - 24.5	24	2	0.1
	25.5 - 29.6	36	79	2.2
	30.6 - 13.7	14	1	0.1
	14.7 - 22.9	71	86	1.2
	23.9 - 18.10	26	9	0.4
1972	3.4 - 16.4	14	34	2.4
	17.4 - 12.5	26	0.4	0.02
	13.5 - 25.5	13	40	3.1
	26.5 - 26.7	60	33	0.5
	27.7 - 24.8	29	107	3.7
	25.8 - 14.9	21	5	0.2
	15.9 - 26.9	12	56	4.7
	27.9 - 7.11	41	8	0.2
Mean for 1969-72	1.4 - 30.9	183	277	1.5

and influence from the neighbouring land area (Bergsten 1955, p. 37).

There are three official meteorological stations close to the Stora Alvaret area (Mörbylånga, Segerstad, and Ölands S. udde) and one at the Uppsala University Ecological Station, Ölands Skogsby, although the latter is unofficial.

Figures of mean yearly precipitation from these four stations for two periods are shown in Table 1. They are roughly between 430—490 mm. The lowest values (429 mm and 430 mm) are obtained from the Ecological Station located at the northern end of the Stora Alvaret. This station represents the northern and largest part of the investigation area, while Mörbylånga and Segerstad are closer to the southern part. There are no particular differences between the stations in these figures. The values of the Ecological Station might be slightly too low as there were some periods in 1977 (March—April and September—October) when regular measurements were not carried out. A certain amount of precipitation might then have been lost by evaporation from the measurement equipment.

Variations in yearly precipitation for these stations within and between years are shown for the investigation period as well (Table 1). In some years the amplitude of variation between the stations is considerable (1972 153 mm) and for other years very small (1977 21 mm, 1975 29 mm). The lowest (1975 314 mm) and the highest (1970 550 mm) values for the period are found at Mörbylånga.

If these four stations are considered to cover the variation of precipitation in the area, the mean values ought to represent the mean annual precipitation in the Alvar.

The mean value for the period (1969—79) is 451 mm but might be slightly too low (see above). The years of the lowest and highest precipitation are 1975 (327 mm) and 1974 (530 mm), respectively.

As the values from the Ecological Station ought to be of the greatest relevance for the main part of the investigated area, these are presented monthly for 1968—80 and as mean values for 1965—80 (Table 2).

For the period 1965—80 the lowest values are shown for June (25 mm) and for January—March (20—22 mm). Extremely low values of monthly precipitation are recorded in some years (March 1969 1 mm, February 1976 1 mm). The lowest summer precipitation was in June 1969 (3 mm) and the highest summer and total value in August 1969 (156 mm). Totally, 1971 has the lowest yearly precipitation (326 mm) and 1974 the highest (539 mm). In summary, this table reveals a wide variation of precipitation within and between years.

Such variations, often with extreme years, appear now and then in areas with low general precipitation. Bergsten (1955 p. 38) gives an example from Ölands N. udde where the mean value during the period 1881—1940 was 406 mm, ranging from 210 mm (1893) to 620 mm (1936). Such variations naturally affect the plant life in these areas, as also stressed by Sterner (1938 p. 22) reporting on shrubs and trees killed by drought, a circumstance also noted by the present author after the dry summers in 1969 and 1975.

A large amount of the precipitation falls in connection with heavy thunderstorms. Such rains often accentuate a local pattern of variation in precipitation. Local variations in monthly values for various years (1973—78) are clearly presented by Widén (1980 p. 102, Fig. 3).

Meteorological stations on Öland provide mean values of precipitation for April—September (1901—30), amounting to about 250 mm (Bergsten 1955 pp. 37 ff.), by Sjögren (1961 p. 12) for 1945—56, and in this paper for 1968—80 (Table 3). An amount of 250 mm is considered to be a critical limit for cultivation without irrigation on Öland. For the Alvar area, figures of that magnitude and even lower are frequent. Precipitation values for a shorter period (May—July) are also presented. The latter period might be considered as critical for the productivity, as low precipitation in that period together with high insolation often creates periods of drought in July—August.

Bergsten (1955 p. 38) and Sjögren (1961 p. 12) show that 54—57% and 51—56% of the precipitation, respectively, fall in April—September. The figures in Table 3 show (1977 excluded) that 58% of the precipitation falls in April—September and 27% in May—July. Only 6% falls in June during this span of years.

Mapping of the precipitation in detail during the growing season is most useful in understanding the drought periods. As four years (1969—72) were used for harvest in permanent plots these years have been treated in detail (Table 4). The figures show extreme values for 1969, with a very dry period lasting from May until August, followed by a very rainy period in late August, and finally a new very dry period until November. In 1970 the distribution during the growing season was more even with only one month of dry conditions in May—June. The precipitation in 1971 was also fairly evenly distributed except for three dry weeks in May and two in June.

The year 1972 had alternate periods of dry and wet weather, and a fairly dry period lasting two months (late May—late July), however, not without scattered rain showers. In August the precipitation was high.

The year 1975, with the lowest values of precipitation for April—September (191 mm) and May—July (76 mm) and the second lowest for yearly values (328 mm) can be mentioned for purposes of comparison: It had six dry weeks (1.6—14.7, 6 mm), ten rainy days (15 mm), three dry weeks (25.7—16.8, 2 mm), one rainy week (33 mm), and then two and a half weeks with dry conditions (25.8—11.9, 4 mm). In the present context the other years will not be given any special attention.

Snow conditions on Öland are very variable. The northern part of Öland receives the largest amounts of snow, gradually decreasing towards the south. The southern part gets a mean snow-depth of 0—20 cm and the northern of 20—30 cm (Östman 1953, map 31). In the southern part of the island the number of days with snow-cover is less than 40, in the middle part 40—60 and in the northern part 60—80 (Ångström 1974 p. 70).

The variation between years is also considerable. In some years there are large amounts of snow, and in others there is little or none. The number of days with snow-cover also varies, but is not necessarily correlated with snow-depth. The number of days with snow-cover for Segerstad varied from 0—129 days and the snow-depth from 0—25 cm within the period 1968—77.

In 1969—70 there was a long period of snow-cover over the entire island, but in 1972—73 there was no snow at all in the southern part and very little in the northern part. Local variations of snow-depth also occur due to topography and vegetation. Snow-drifts formed to the leeward side of the junipers on the Alvar are discussed in Chapter 6.

The duration of snow-cover seems to coincide fairly well with the number of days with a mean temperature below 0°C (Ångström 1974 p. 69).

1.3.2 Other climatic features

Temperature

The influence of the Baltic sea creates a local maritime temperature climate for Öland and the eastern coast of the Swedish mainland (Ångström 1974 p. 53), characterized by a rather cold and late spring and a fairly warm and long autumn. For Öland the mean temperature amplitude throughout the year is lower than on the mainland but the yearly mean temperature is higher. From Ölands N. udde, the station with the most mari-

Table 5. Mean temperatures (°C) for February (F), July (J), and year (Y) in 1921 50, and yearly during 1969-72 for three meteorological stations on Öland.

	1921-50			1969			1970			1971			1972		
	F	J	Y	F	J	Y	F	J	Y	F	J	Y	F	J	Y
Ölands N. udde	-0.9	17.4	7.4	-2.2	18.1	7.0	-2.9	15.3	5.8	0.3	16.3	7.2	0.0	18.6	7.6
Ekerum	-1.8	17.1	7.0	-3.2	18.5	6.7	-7.6	15.4	5.6	-0.1	17.2	7.2	-0.3	-	-
Ölands S. udde	-0.8	16.3	7.1	-1.9	16.3	6.9	-4.6	13.6	5.9	0.7	15.3	7.0	0.6	17.5	7.6

Table 6. Monthly mean maximum temperatures (°C), April-October, 1969-1972, at the Ecological Station, Ölands Skogsby.

	A	M	J	J	A	S	O	Mean
1969	10.1	16.3	20.3	23.4	21.7	18.3	13.2	17.6
1970	5.8	13.5	20.9	19.3	19.9	16.2	11.5	15.3
1971	8.6	16.1	17.4	21.7	21.1	13.4	13.0	15.9
1972	9.5	14.1	19.8	24.0	20.2	15.9	11.1	16.4

time position on Öland, the amplitude is 17.2°C, which may be compared with Mörbylånga with 18.5°C and Sandbäckshult (on the mainland about 10 km from the sea) with 18.1°C for the period 1901—30 (Bergsten 1955 p. 37). The yearly mean values for these three stations during the same period are 7.2, 6.6, and 5.7°C, respectively. Sjögren (1961 p. 11) reports 7.4, 7.4, and 6.5°C for the same stations in 1935—47.

The coldest month is February with mean values for the whole island between —2°C and —1°C. July is the warmest month with 16—17°C (Ångström 1953, maps 25—26). Laaksonen (1979 p. 111) reports 16.5°C for the southern part.

Laaksonen (1979 p. 120) gives figures for mean temperatures in 1921—50 and using these figures mean temperatures for February, July, and for year are given for three meteorological stations on Öland (Table 5). The Ekerum station has the lowest figures for February and for year as it is not located as close to the sea as the other stations.

Values for the same months and stations as above are also given for 1969—72 (Table 5), the period when harvests were carried out in permanent plots (see below). In comparison with the values for 1921—50, February shows lower values in 1969 and in 1970, but higher in 1971 and in 1972. The temperatures for July are higher in 1972 and in 1969, and lower in 1970 and 1971. During the period 1969—72 the lowest or highest values were not always found in these two months. Yearly mean temperatures were higher in 1972, about normal in 1971, lower in 1969, and very much lower in 1970.

As no mean temperature values have been calculated for 1969—72 from the Ecological Station the monthly mean maximum temperatures are given instead (Table 6). Comparison of mean values for the whole period April—October, shows the highest for 1969, followed by 1972, 1971, and 1970. The highest monthly mean maximum temperature was for July 1972. The highest daily max. temperature (31°C) was registered on 20 June 1970.

Growing season

The period when conditions are suitable for plant growth is often defined (in Sweden) as the period when daily mean temperature exceeds +3°C. Using that criterion, Öland is within the 220—230 day interval per year (Ångström 1974 p. 58). However, Sjörs (1965a p. 10) disputes the suitability of this threshold as it favours areas with strongly oceanic conditions. Instead, he proposes a +6°C threshold, which would fairly well correspond to the zonation of major vegetational regions in Sweden. Using that isoline (+6°C), Öland has a growing period of 180—200 days per year (Langlet 1936 p. 373).

In the beginning and at the end of the growing season plants risk frost exposure at night. The occurrence of frost on Öland is calculated to be 0—2 days at a threshold of +6°C (Ångström 1974 p. 76).

Tuhkanen (1980 p. 76) defines the growing season as "that period over which the daily mean temperature remains above +5°C". Using that definition Öland would have a growing season of 210—220 days per year. Because Tukhanen's study was the most thorough one I adopted this definition.

Humidity

Values for humidity in Sweden were calculated by Hesselman (1932 pp. 530 ff.). He used the Martonne index ($P/(T+10)$, where P is the annual precipitation and T the mean annual temperature) to produce a map of humidity for Sweden. His calculations show a humidity value less than 30 for Öland. For the vegetation period Ångström (1953, map 26) gives the values 20—24 for Öland and the neighbouring coastal part of the mainland (using the same but slightly modified method). These figures classify Öland as a sub-arid region. In comparison it might be mentioned that the highest values for Sweden are above 56. Many parts of the Russian

black earth region have humidity figures similar to those on Öland (Sjögren 1961 p. 12).

The potential evapotranspiration for the growing season in Öland is 540—560 mm (according to Thornthwaite). His moisture index gives —10 for Öland (Tuhkanen 1980 pp. 77 ff.).

Mist

As Öland is surrounded by the sea it has higher mist frequency than the mainland, as also shown by Sjögren (1961 p. 13). The meteorological station in Kalmar (on the mainland) is an exception with 44 days. In the southern part of Öland there is a mist frequency of 15—20% of the total number of days and for the northern part 10—15% (Ångström 1974 p. 120). On the Alvar the values might be slightly lower as the area is not situated close to the sea where most of the meteorological stations are located.

Sunshine

In connection with low precipitation, high values for the number of sunshine hours per year on Öland are given, with about 2000 hours for the very south and north ends of Öland, and slightly less for the rest of the island (Lindholm 1955). For Sweden this value is very high and should be compared with 1600 hours for the southwestern part of the country (Königsson 1968 p. 18).

In figures for Ölands S. udde (1961—77) there is a variation between 1640 and 2290, with a mean value of 1906 hours (Widén 1980 p. 101).

Winds

For the southern part of Öland, SW to W winds predominate during the year. In spring, NE to E winds are frequent in the southern part of the Baltic, whereas in summer they are SW to WNW, in autumn SW and NE, and in winter SW to W. Roughly the same conditions apply to Ölands S. udde (Östman 1926 pp. 15 ff.).

In winter, hard climatic conditions abruptly appear in the Swedish southeastern coastal areas, when hard cyclonic winds may bring large amounts of snow from the E or NE. Östman (1926 p. 7) reports frequent wind forces of 7 Beaufort and more for SW to WSW winds during the year on the southern part of the island. During the winter, winds of that strength are most frequent from N to NE.

A high wind frequency accentuates the low precipitation level on Öland through increased evaporation, which in turn makes the drought situation worse for the vegetation, especially in open areas such as the Alvar, which also have high insolation.

Microclimate

Microclimatic conditions probably are highly important for the pattern of distribution for various taxa in the Alvar, both plants and animals. No measurements in this respect have been made in the present investigation. However, some figures are known from the Alvar from measurements made during studies of insects and their habitats. Coulianos (1973 pp. 118 ff.) studied four habitats: (1) S-exposed part of a strip of vegetation, (2) N-exposed part of same strip, (3) surface of bedrock under 1 cm thick layer of *Cladonia pyxidata* var. *pocillum*, and (4) in the middle of a 10 cm thick layer of *Pleurozium schreberi* under a juniper, N-exposed. Conditions in the air (175 cm above ground) were measured to provide reference values. His results are summarized below:

For 24-hours with dry, steady radiation weather (dew at night) during 10—11 June, 1963, the following results were obtained: Amplitude of temperature variation during the period was highest for (1) and then decreased in the order (2), (3), air, and (4). The minimum temperatures were highest for (1), (2), and (3) (almost equally high), lower for (4), and lowest for the air. Storage of heat in the bedrock favoured (1)—(3).

The variation in relative humidity was about the same for (3) and air (25—95%), then lower for (1) and (2) (about 50—100%) and lowest for (4) (85—100%). On the surface of the moss layer, 50% was obtained during the day. The highest maximum temperature of about 41°C was at (1), and about 21°C for air.

Values within 24 hours in cloudy conditions were measured. They gave about the same shape of thermohygrogram, but with lower amplitudes.

The importance of heat stored in the ground for formation of "microclimatic carpets" is discussed in 8.1.1 (according to Lange 1979), and the effect of wind speed in 2.2.5.

Precipitation and temperature have been stressed in this chapter as factors which play a major role in the productivity and dynamics of the Alvar. The use of climatic parameters and indices for zonal distribution of vegetation are shown and discussed by Tuhkanen (1980). He found that potential evapotranspiration coincides most closely with vegetational zone boundaries in Sweden and Finland, but also good correlations were found with length of growing season and the effective temperature sum (°C) during the growing season (the latter being 45—50°C for Öland). The southern part of Öland is within the southern deciduous region of Sweden, which is at the border of the large West and Central European Nemoral zone (Sjörs 1965b p. 51).

As the meteorological stations are not located on the Alvar the values presented above may not in all respects be representative for the open treeless area. Local variations such as ridges, depressions, permanent lakes and the occurrence of shrub vegetation also might influence the climatic conditions.

2 Flora and vegetation of Öland

Since the 18th century the flora of Öland has been known to contain many species not found in other parts of Sweden. During his journeys through different parts of Sweden, Linnaeus visited Öland in 1741 to investigate plants for dyes and medical uses, etc. In his diary of June 1, when he made the crossing from the mainland to Färjestaden on Öland, Linnaeus remarked: "We had hardly reached the shore of Öland before we realised that the island was quite different to the provinces of Sweden; therefore we determined to make our notes on everything that occurred on the island the more detailed" (free translation by the author from Linnaeus 1745 p. 50).

In his diary he also recorded the species found, and made notes on them and the vegetation. He mentions a great number of species specific to the flora of Öland, among these finding 37 taxa new for Sweden (Sterner 1926 p. 2). During his stay on Öland (three weeks) he also made observations on people, agriculture and traditions, etc.

Since the time of Linnaeus, many persons have taken part in the exploration of the Ölandic flora. In the late 18th century and the early 19th century, most of the well-known botanists in Sweden visited Öland (Sterner 1926 p. 7). A review mainly based on Sterner (op. cit. pp. 8 ff.) is given below.

In 1818 and 1824 one of the most well-known Swedish scientists in taxonomic botany, Elias Fries visited Öland. He discovered many new species and classified some critical taxa.

One of the founders of plant geography in Sweden, Göran Wahlenberg, visited Öland in 1821. He treated the relations between vegetation and the geography of the landscape (1821).

Among the successful botanists of that time, mention should be made of Abraham Ahlqvist, a rural dean born on Öland. He wrote *Flora Runsteniensis* (1815—1817), a very detailed parish-flora, and later a work about the vegetation on Öland (1821). He reported that 751 species were known on Öland at that time.

M. G. Sjöstrand, a pupil of Elias Fries, later priest on Öland, published a list of species with information on their distribution on Öland (1850), and later a flora (1863). In his thesis, 862 species were mentioned (no vascular cryptogams except for *Equisetum*).

During the latter half of the 19th century, Öland became a very popular place for botanical excursions. Many people added to the knowledge about flora and vegetation of the island. For example: C. Stenhammar and M. M. Floderus were the first to write about the lichen flora, E. V. Ekstrand wrote on the moss flora as also did J. E. Zetterstedt.

Many years passed until the plant geographical works of Ahlqvist and Wahlenberg were succeeded by new works in these fields. Many scientists became interested in the very specific alvar vegetation. A. Y. Grevillius published a work in 1896 about the composition of the Alvar vegetation with morphological and anatomic aspects of involved taxa. H. Witte wrote about the ecology of alvar species (1906a—c) and K. Falck about temperature, humidity and osmotic pressure (1913). G. Einar Du Rietz studied sociological aspects of alvar vegetation, especially concerning lichen and *Helianthemum oelandicum* associations (1923).

Rikard Sterner published many important works about the flora and the vegetation of Öland. His thesis (1926) on the plant cover of Öland (*Ölands växtvärld*) included descriptions of plant communities related to edaphic and climatic conditions. His *Flora der Insel Öland* (1938) contains a large number of distribution maps and autecological aspects are given for 1050 of the persistently present species on the island, as well as some subspecies and accidental species. In *Ölands Flora* (1948) still more information was added.

Nils Albertson gave a plant sociological survey of alvar vegetation (1950); a work today used as a reference by many botanists. Inga Arvidsson wrote about water absorption and drought resistance in some taxa in alvar vegetation (1951).

Among today's botanists, Erik Sjögren should be mentioned, with two comprehensive works on moss vegetation in deciduous forests of Öland (1961, 1964). Lars-König Königsson (1968) studied changes in the holocene vegetation history, based on pollen analysis. Åke Lundqvist added two supplements to Sterner's Flora (1970, 1979). Lars Rodenborg has published reports and a large work on changes in land use and plant cover with historical aspects from an old grazing area in central Öland (1976), as well as a publication on lichens (1977). Mohamed Ammar (1978) compared vegetation types on beach ridges at Vickleby, using multivariate analysis. A taxonomic and autecological research giving valuable information on the *Helianthemum* taxa was carried out by Björn Widén (1980).

2.1 Flora

The landscape of Öland, providing a wide range of environmental conditions for the plants, has a very interesting flora, which largely differs from that found in the rest of Sweden, except on the island of Gotland.

Sterner mentions (1948 pp. 97 ff.) 12 species and 3 subspecies in the Ölandic flora, which are not found elsewhere in Sweden; all except 2 are not known elsewhere in the Nordic area.

Today another taxon can be added to those found only on Öland, but not elsewhere in the Nordic area. It was collected in 1946 but identified only in 1976 as *Allium strictum* Schrad. Later it has also been refound in the field (Lundgren 1976 pp. 193 ff.).

In addition, Sterner (1948 p. 97 ff.) reported that there were 16 species common to Öland and Gotland, but absent in the rest of Sweden, and two species common to Öland and Scania. Of these 18 species only two were known from the rest of the Nordic area. However, today the situation is slightly different. One of the species has now disappeared completely, and a few have been found in other provinces. The lists given below have been corrected in that respect. According to Sterner's (1948 pp. 222 ff.) descriptions, no less than 10 taxa, most of them on the ssp. and var. level are endemic.

Taxa in the Nordic area found only on Öland:

Artemisia laciniata
Plantago tenuiflora
Orobanche purpurea
Ranunculus illyricus
Viola alba
V. eliator
Allium strictum
Helianthemum oelandicum complex, including *H. canum* and *H. rupifragum*

Ulmus laevis is found on Öland and in SE Finland.

Taxa common to Öland and Gotland:

Artemisia rupestris
Aster linosyris
Globularia vulgaris
Galium rotundifolium
Orobanche alba
Adonis vernalis
Anemone sylvestris
Sisymbrium supinum
Viola pumila
Fumana procumbens
Potentilla fruticosa
Coronilla emerus
Ulmus carpinifolia
Anacamptis pyramidalis
Apera interrupta

Peucedanum oreoselinum is found on Öland and in Scania.

Some examples of species common on Öland (alvar areas) but rare on the mainland:

Orchis ustulata
Prunella grandiflora
Oxytropis campestris
Hornungia petraea
Cerastium pumilum

On the other hand, there are about one hundred species found on the mainland but lacking on Öland.

The flora of Öland consists of many floral elements such as Siberian, Southeast European, South European, Southwest European and some North European (alpine/montane) elements. Some endemic taxa complete the floristic features.

The following list gives examples of elements found in alvar areas (Sterner 1948 pp. 204 ff., 1955b pp. 88 ff.):

Siberian group

Artemisia laciniata
A. rupestris
Carex obtusata
Oxytropis campestris
Allium strictum

Southeast European group

Plantago tenuiflora
Ranunculus illyricus
Anemone pratensis
Potentilla arenaria
P. tabernaemontani
Aster linosyris
Polygala comosa
Gypsophila fastigiata
Viola pumila
Prunella grandiflora
Vincetoxicum hirundinaria
Galium triandrum

South European group

Fumana procumbens
Helianthemum oelandicum complex
Apera interrupta
Veronica praecox
Hornungia petraea
Holosteum umbellatum
Cerastium pumilum
Tunica prolifera
Poa bulbosa
Coronilla emerus
Anthericum liliago
A. ramosum
Sisymbrium supinum
Globularia vulgaris

Southwest European group

Teesdalia nudicaulis
Hedera helix
Echinodorus ranunculoides
Littorella uniflora

North European group (alpine/montane)

Poa alpina
Viscaria alpina coll.
Draba incana
Potentilla crantzii
Asplenium viride
Polystichum lonchitis

Endemic group

Helianthemum oelandicum
Festuca rubra ssp. *oelandica*
Crepis tectorum ssp. *pumila*
Galium pumilum ssp. *oelandicum*
Silene maritima var. *petraea*
Allium schoenoprasum var. *alvarense*
Senecio jacobaea ssp. *gotlandicus*
Viscaria alpina var. *oelandica*
Primula farinosa var. *acaulis*
Plantago tenuiflora var. *depressa*

Many of the taxa mentioned above belong to steppe vegetation in those areas where they have their main distribution.

Compared with the southernmost provinces in Sweden, Öland has the largest number of Siberian and Southeastern elements, but less of the Southern and Southwestern elements. On the Alvar there are also some taxa which may principally be considered as seashore plants, such as *Plantago maritima, Armeria maritima*, and *Silene maritima* (on the Alvar var. *petraea*). Some of the Alvar species found in the southern part of the island are not found in the northern part and vice versa. Most of the Swedish orchid taxa (29 of 44) are also found on Öland (Sterner 1948 p. 199).

The reason for this comprehensive presentation of the flora of Öland, especially of taxa of the Alvar areas, is to emphasize the unique composition which must be considered when protection is planned against threats of various kinds. Furthermore, most of the literature on the flora and vegetation of the Alvar is written in Swedish and is thus difficult for international readers to use.

2.2 Vegetation

The vegetation on Öland is very mosaic due to geological, edaphic, climatic, and cultural conditions. In addition to the Alvar, biotopes such as woods, wet areas (fens, pools, lakes), sea shores, dry sandy areas, are found, apart from agricultural land. Characteristics of three other biotopes related to the Alvar are summarized below.

2.2.1 Woods

Woods cover about 20% of the total area of the island. Deciduous woods predominate, followed by pine woods, mixed coniferous-deciduous woods, mixed coniferous woods, and spruce woods.

Coniferous woods are mainly found in the northernmost part of the island and scattered along the western coast. The largest deciduous wood area is found in the central part of the island (Mittlandsskogen), from the Stora Alvaret in the south and almost to Borgholm in the north. Small deciduous woods, surrounded by agricultural land, are fairly numerous all over Öland. Isolated deciduous woods are also found in some parts of the alvar close to old villages.

Conifers, mostly pines, have been planted for forestry, windshelter, and firewood. They form small enclaves in the open landscape, along beach ridges as well as in alvar areas.

Following severe exploitation in the 19th century, large areas at the border of the Alvar and former meadows in the woods are now overgrown with trees and shrubs. Dense nearly pure shrub areas of *Corylus avellana* ("hässlen") occur in some places.

The dominant forest is the *Quercus robur - Betula verrucosa* type, in some places with a *Corylus avellana* variant and in others with a *Juniperus communis* variant (Sjögren 1964 pp. 16 ff.). Small, more or less pure woods of *Carpinus betulus, Tilia cordata, Fraxinus excelsior - Ulmus glabra*, and in wet areas *Alnus glutinosa - Betula pubescens* are found. Mixed woods appear, often with *Populus tremula* involved; further information is found in Sterner (1926, 1938, 1948, 1955 a,c,d), Sjögren (1961, 1964), and Ekstam & Sjögren (1973).

2.2.2 Wet areas

Various types of wet meadows and fens, occur both in open grassland and in woodland, sometimes drying out in summer (cf. 2.2.4). A large number of fens were drained 50—100 years ago, e.g., along the eastern border of the Stora Alvaret. Most of the fens are classified as eutrophic but in the north some are oligotrophic.

In the wettest fen types *Scirpus tabernaemontani, Typha angustifolia, Phragmites communis, Equisetum fluviatile*, and *Carex elata* are dominant. *Claudium mariscus* is frequent locally (Sterner 1938 p. 32).

In less wet fen types *Schoenus ferrugineus, S. nigricans*, numerous *Carex* spp. and orchids, e.g. *Orchis militaris, Dactylorhiza incarnata, Epipactis palustris*, and *Ophrys insectifera* are found (Lundqvist 1955 pp. 98 ff.).

Iris pseudacorus, Carex riparia, and *Lysimachia thyrsiflora* are frequent in fen types in woods. Further information is given in Sterner (1926, 1948). Only one real lake is found on Öland, in the northern part.

2.2.3 Sea shores

The sea shore vegetation is highly variable due to exposure and substrate. In large areas till deposits predominate, giving a stony coastline with ridges forming small tongues of land. Sandy areas are most dominant in the

northern part, where dunes are found. A characteristic coastline type with bare calcareous rock extending into the sea is common in the NW and SE. In the SW shale pebble beach ridges are found.

The richest shore vegetation is found along the central western coast. A few characteristic taxa, frequent around the island, are: *Aster tripolium, Glaux maritima, Juncus gerardi, Eleocharis uniglumis* var. *fennicus* and *Triglochin maritimum*, whereas *Eryngium maritimum, Crambe maritima*, and *Lathyrus maritimus* are very rare.

In a few places there are transitions gradually from shore vegetation to alvar vegetation; further information about shores is given in Sterner (1948 pp. 152 ff.).

2.2.4 Alvar vegetation

Vegetation in alvar areas is very complex and rich in taxa, consisting of a mosaic of plant communities. Most foreign floral elements are found in the heathlike limestone area, forming several plant communities due to very varying habitat conditions. As mentioned in connection with the discussion on flora, many steppe elements are found in the Alvar, but the Alvar cannot be considered as a steppe itself, as there are major soil and climatic differences.

A steppe area has a thick soil layer (several metres) compared with the thin soil layer (a few centimetres or decimetres) on the Alvar. The Alvar vegetation is also more complex, with heathlike parts dominated by dwarf shrubs, mosses and lichens, which is not the case in a real steppe. Frost-induced soil movements occur frequently in some parts of alvar areas, but not in steppe vegetation (Sterner 1926 pp. 92 ff.).

Frost-induced soil movements, occurrence of dwarf shrub communities (with mosses and lichens) and characteristics in snow and wind conditions are in common with high mountain heathlands. In contrast, most species are not in common with such areas. The widespread annual plants on the Alvar are almost absent in the mountains. Annual development of the plant cover also differs.

Some parts of the Alvar vegetation on bare rock surfaces and in karst areas are very similar to vegetation in central and south European rocky limestone areas as regards common taxa and composition of vegetation. However, dwarf shrub, moss and lichen communities cover large areas of the Alvar, a feature which does not occur in the Middle European vegetation. Naturally, differences in topography and climate must also be considered (Plate 1:1).

Alvar vegetation similar to that on Öland is found in Gotland (Pettersson 1958, 1965), in Estonia (Vilberg 1927; Laasimer 1965), and in some very small areas in W Sweden (Albertson 1946).

There are different ways to classify the components of alvar vegetation. Sterner (1926 pp. 51 ff.) referred principally to dominant taxa. A more modern sociological classification was applied by Albertson (1950), based on constellations of plant species. The latter approach provides a more precise and detailed description of the vegetation and will be used in the following.

A fairly comprehensive description of alvar communities is given below, showing the richness of communities available for grazing.

Plant communities of exposed rock

Albertson distinguished three associations, briefly reviewed below.

1. *Lecanora calcarea - Verrucaria nigrescens* ass. (*Lecanoretum calcareae*, p. 282). Represented by xerophilous lichen taxa which grow directly on exposed rock; often well developed in karst areas, on heavily weathered limestone.

2. *Collema cristatum - Collema tunaeforme* ass. (*Collematetum tunaeformis*, p. 283). Differs from *Lecanoretum* as it is characteristic on bedrock in depressions where seasonal flooding occurs, giving this association a hydrophile phase.

3. *Sedum album - Tortella tortuosa* ass. (*Sedetum tortellosum*, p. 284). On exposed bedrock where small amounts of soil occur in patches locally. Most important mosses are *Schistidium apocarpum, Tortella tortuosa, T. inclinata*, and *T. rigens*. On thin layers of weathered soil the lichens *Cladonia symphycarpa, Lecidea decipiens, Toninia coeruleonigricans, Squamarina crassa, Fulgensia fulgens*, and *F. bracteata* are also common. In the field layer *Sedum album, Allium schoenoprasum* var. *alvarense, Crepis tectorum* var. *pumila, Poa alpina, Cerastium pumilum*, and *Erophila verna* appear (Plate 3:6).

Fig. 3. Exposed bedrock with characteristic fissures are found in parts of the Stora Alvaret, but in limited areas. In these karst areas the "*Sedetum tortellosum*" association is found on the bedrock, together with crustaceous lichens as *Lecanora calcarea. Juniperus communis, Prunus spinosa,* and *Corylus avellana* may be found in the fissures together with taxa such as *Polygonatum odoratum, Lactuca muralis, Asplenium trichomanes,* and *A. ruta-muraria.* — Alvar of Nedre Ålebäck. February 1968. Photo E. Sjögren.

Vegetation in karst areas

There is often a mixture of *Lecanoretum calcareae* and *Sedetum tortellosum* due to local variations of the exposed rock. Along the fissures in the bedrock we find lichens such as *Caloplaca chalybaea, Lecidea immersa,* and *Physcia caesia* (Albertson 1950 pp. 282 ff.).

Many shrubs and other specimens find a refuge in the fissures where soil often accumulates and where microclimatic conditions differ from the surrounding exposed rock. Common shrubs are *Rosa* spp., *Cotoneaster melanocarpa, C. integerrima, Prunus spinosa, Rhamnus catharticus, Juniperus communis,* and *Crataegus* spp. Locally *Betula verrucosa* and *Corylus avellana* are found (Fig. 3). Mosses as *Barbilophozia barbata, Anomodon viticulosus, Encalypta contorta,* and *Conocephalum conicum* may be found as well (Sterner 1926 pp. 54 ff.; Albertson 1950 pp. 322 ff.).

Examples of other taxa: *Polygonatum odoratum, Geranium sanguineum, Melica ciliata, Vincetoxicum hirundinaria, Lactuca muralis, Lithospermum officinale, Dryopteris filix-mas, Cystopteris fragilis, Asplenium trichomanes, A. ruta-muraria,* but also *Circaea lutetiana, Sanicula europea, Coronilla emerus,* and *Polystichum lonchitis* (Sterner 1926 pp. 54 ff.).

In the shade of higher shrubs, growing in the fissures, a moss layer is developed with dominance of *Camptothecium lutescens* and *Thuidium abietinum* but also *Tortula ruralis* and *Rhytidium rugosum* (Albertson 1950 p. 323).

Plant communities on weathering deposits

Depending on thickness of the soil and due to moisture conditions the following associations may be distinguished:

1. *Festuca ovina - F. rubra* var. *oelandica - Tortella tortuosa* ass. (*Festucetum alvarense tortellosum,* Albertson 1950 p. 289). On thin, frequently temporarily flooded soils. With transitions to *Sedetum*

Fig. 4. *Festucetum* associations are found on thin weathering deposits. In this vegetation graminids are dominant, such as *Festuca ovina, F. rubra* var. *oelandica,* and *Agrostis stolonifera. Artemisia rupestris, Leontodon autumnalis, Helianthemum oelandicum,* and *Thymus serpyllum* are frequent together with annual hapaxanths. *Juniperus communis* may colonize fissures in the bedrock, as seen in the background. — Alvar of Stenåsa. August 1975.

tortellosum. In addition to species giving the name to the ass., species as *Agrostis stolonifera, Poa alpina, Artemisia rupestris, Leontodon autumnalis, Hieracium* spp. and often *Helianthemum oelandicum* are found (Fig. 4). Species such as *Cladonia symphycarpa, Lecidea decipiens, Barbula* spp. and *Riccia* spp. occur in the bottom layer. For detailed information see Albertson (1950 pp. 289 ff.).

2. *Helianthemum oelandicum - Festuca ovina - Cetraria islandica* ass. (*Festucetum alvarense cetrariosum,* op. cit. p. 296). On rarely or not flooded areas. Sometimes subassociations appear with only *Helianthemum oelandicum* or *Festuca ovina* as dominants, but they often occur as codominants (Plate 3:5).

Other common species are *Thymus serpyllum, Agrostis gigantea, Phleum nodosum, Galium pumilum* ssp. *oelandicum, Gypsophila fastigiata, Silene maritima* var. *petraea,* but also *Globularia vulgaris* and *Vincetoxicum hirundinaria* and in the NE part of the Stora Alvaret, *Fumana procumbens.*

In the bottom layer, *Cetraria islandica* (dominant), *C. nivalis, Cornicularia aculeata, Thamnolia vermicularis* are found, but also *Cetraria cucullata* and *Cladonia* spp. Mosses are rare, but some species might be mentioned: *Barbula fallax, Camptothecium lutescens, Ditrichum flexicaule,* and *Rhytidium rugosum.*

3. *Sedum rupestre - Festuca ovina - Rhacomitrium canescens* ass. (*Festucetum alvarense rhacomitriosum,* op. cit. p. 300). In drier localities with thicker soil than areas where *Festucetum cetrariosum* is found. *Festuca ovina* is dominant together with *Cladonia arbuscula, Rhacomitrium canescens,* and *Dicranum scoparium.* Species such as *Agrostis tenuis, A. canina, Dianthus deltoides, Potentilla arenaria, Sedum reflexum,* and *Scleranthus perennis* are common.

Transitions to the *Avenetum* are common. *Festucetum cetrariosum* and *Festucetum rhacomitriosum* are the most frequent plant associations in the Alvar, forming large heaths.

Plant communities on gravelly deposits

1. *Avena pratensis - Sesleria coerulea - Camptothecium lutescens* ass. (*Avenetum alvarense,* op. cit. p. 304). On much thicker soils than the abovementioned associations. Restricted to areas with till or littoral material, often relatively poor in lime. In composition, this ass. is very similar to dry meadow vegetation in many parts of SE Sweden, but there are major differences, such as the large number of foreign floral elements. *Helianthemum oelandicum* also occurs in this ass. *Festuca ovina* is mostly dominant. Characteristic species are *Arrhenatherum pratense* (= *Avena pratensis*), *Sesleria coerulea, Briza media, Phleum phleoides,* and *Sieglingia decumbens,* which separate the *Avenetum* from the *Festucetum.*

Typical species of the *Avenetum* are, e.g., *Anemone pratensis, Artemisia laciniata, Aster linosyris, Polygala comosa, Prunella grandiflora, Ranunculus illyricus, Scabiosa columbaria, Oxytropis campestris, Filipendula vulgaris, Anthyllis vulneraria, Orchis mascula,* and *O. ustulata.*

Areas with scattered junipers are frequent in the *Avenetum,* locally forming a dense scrub at the borders of the Alvar or in areas not sufficiently grazed. *Prunus spinosa* and *Calluna vulgaris* also

Fig. 5. The "*Avenetum alvarense*" association develops in areas with gravelly deposits. This vegetation is characterized by a high species diversity. *Festuca ovina* and *Arrhenatherum pratense* are frequently dominant; taxa such as *Filipendula vulgaris, Artemisia laciniata, Oxytropis campestris, Helianthemum nummularium,* and *Anemone pratensis* are frequently present. The photograph, taken close to the permanent plots with junipers, shows an alvar area that has been weakly grazed by cattle. The juniper cover is increasing. *Sorbus intermedia* is seen in the distance. — Alvar of Nedre Ålebäck. 11 October 1970.

appear and single colonizing specimens of *Picea abies, Pinus sylvestris, Betula verrucosa,* and *Sorbus intermedia* (Fig. 5).

Vegetation in alvar lakes and fens

According to Königsson (1968 p. 52), alvar lakes and fens may be created in (a) depressions in the bedrock or in (b) the basin between the alvar surface and a damming gravelly formation, which may be combined with a scarp (or another bedrock feature).

The alvar lakes are physiognomically characterized by a central fen community, surrounded by a free water zone. In the central part, *Carex elata* (dominant), *Phragmites communis, Scirpus lacustris, S. tabernaemontani, Carex lasiocarpa,* and *Equisetum fluviatile* occur as well as *Menyanthes trifoliata* (Albertson 1950 p. 320).

In the free water zone *Chara contraria* and *C. aspera* occur and such taxa as *Potamogeton natans, P. gramineus, Polygonum amphibium, Glyceria fluitans,* and *Myriophyllum alterniflorum.* In shallow parts, *Littorella uniflora* often forms dense carpets (Königsson 1968 pp. 52 ff.).

Vegetation of alvar pools

Two kinds of pools may be distinguished (a) ephemeral and (b) persistent pools (Königsson 1968 pp. 50 ff.). The first type (a) is found in extremely shallow depressions, and dries out fairly rapidly

following the snow-melt or after a period of rains. Very little sediment is produced.

The persistent pools (b) are found in basins where water is retained during the main part of a year with normal precipitation. They may become dry for a short period in summer.

Königsson (op. cit. p. 51) distinguishes four situations in which these pools are formed namely: "(I) dammed by scarps, (II) existing in other depressions in the bedrock, (III) dammed by gravelly ridges (which however very often are combined with scarps), (IV) in depressions within the gravelly deposits."

Albertson (1950 pp. 313 ff.) gave a preliminary classification of the vegetation of these pools (Sw. "vätar"):

1. *Agrostis stolonifera - Alopecurus geniculatus - Scorpidium turgescens* ass.

2. *Taraxacum limnanthes - Carex panicea - Scorpidium turgescens* ass.

3. *Carex oederi - Scirpus palustris - Scorpidium scorpioides* ass.

In addition to the species mentioned in the names of the three associations, other species are found, e.g., *Litorella uniflora, Plantago tenuiflora, Sisymbrium supinum, Inula britannica, Teucrium scordium, Plantago maritima,* and *Veronica catenata.*

Common mosses are *Scorpidium* spp., *Campylium stellatum, C. elodes, Drepanocladus intermedius, Bryum* spp., and *Riccia* spp.

Plant communities of wet meadows

Wet meadows are found in many areas which are temporarily flooded or located along the edges of alvar lakes or pools. They are often found on limestone-rich till. Albertson (1950) classified them as a *Sesleria coerulea - Molinia coerulea - Ctenidium molluscum* ass. (*Molinietum alvarense,* op. cit. p. 310), in the Alvar mostly as *Sesleria* meadows, often with *Potentilla fruticosa.* Species differentiating this association from the *Avenetum* are *Carex hostiana,* and *C. panicea.* Species such as *Carex tomentosa, Agrostis gigantea, Gentianella uliginosa, Parnassia palustris, Primula farinosa, Scutellaria hastifolia, Salix repens* coll., *Potentilla crantzii,* and *Viola pumila* are common.

2.2.5 Various adaptations in alvar species due to climatic conditions

In the Alvar vegetation a number of taxa differ in general habit and shape from their appearance in other biotopes. They are often much smaller, more frequently prostrate, more hairy or wax-covered. Variations in the colour of flowers and of leaves also appear.

Most of the alvar vegetation is considered as xerophilous. Its components have to withstand both water and nutrient deficits. Xerophilous vegetation types are known to include dwarf forms of the taxa involved. A diminuition in all parts of a plant is often termed nanism, and a reduction of only above-ground parts may be called semi-nanism (Witte 1906c p. 54).

Witte considered nutrient and water deficits to be the main reason for the common occurrence of dwarf forms in the Alvar vegetation (op. cit. p. 56). Water deficits were regarded to be partly due to transpiration caused by frequent strong winds and strong insolation.

According to the same author (op. cit. pp. 56 ff.), the dwarf plants are described as shorter, unbranched or less branched, and having a smaller number of leaves, often reduced in size or/and of a more simple form (e.g. less serrated) than normally, and a smaller number of flowers, sometimes also of smaller size. Some taxa are characterized by less branched root systems. However, there are also dwarfs with normal proportions, or even with exceptionally large root systems, which is a common feature in plants on dry soils. Several dwarfs are annuals, usually wintering hapaxants (living from autumn to spring). Otherwise biennal plants here often appear as perennials.

The adaptations to the severe edaphic and climatic conditions of the Alvar have been summarized as follows, according to Witte: — Periodic decrease of the leaf surface when curled, or survival during the driest period through seeds only (*Arenaria serpyllifolia*) or through bulbs (*Ranunculus bulbosus*). — Permanent surface reduction, e.g. by narrow leaves (*Poa angustifolia*). — Dense growth form, often with a rosette, or branched close to the ground (the latter in *Thymus serpyllum*). — Protection from wind and sunshine by hairs (*Ranunculus illyricus*). — Protection from desiccation by a wax-cover (*Silene maritima* var. *petraea*). — Sunken stomata (*Festuca ovina*). — Thick pallisade parenchyma (*Prunella vulgaris*). — Storage of water by succulency (*Sedum*

spp.). — Protection from irradiation by red or violet pigments in the epidermis (*Sedum album*). — Lignification of stems and branches (*Gypsophila fastigiata*).

Many plants expose the upper part of the root or rhizome above ground, probably due to uplift by frost-induced soil movements (Witte op. cit.). There are different types of roots such as:

Taproot. Thin taproot without storage ability (*Linum catharticum*). — Thick taproot with storage ability (*Carlina vulgaris*). — Thick lignified taproot (*Helianthemum* spp.).

Adventitious roots. A more or less well-developed rhizome with roots (*Vincetoxicum hirundinaria*). *Filipendula vulgaris* has tubers for nutrient storage on the roots. —Long thin roots from a tufted basal stem system (*Festuca ovina*). — Underground runners (soboles), often lignified, with roots (*Galium verum*). — Stems creeping on the soil surface, and producing roots (*Sedum* spp.). —Onions or other kinds of bulbs, with roots (*Allium schoenoprasum*).

Falck (1913 pp. 349 ff.) showed generally *higher osmotic values* for plants in the Alvar, in comparison with less extreme habitats. The highest osmotic pressure (about 55 atm.) was found in *Helianthemum oelandicum*. A combination of edaphic and climatic factors was considered to condition the xerophilous vegetation found in the Alvar. For further information about osmotic values and water as an ecological factor in general, see e.g., Walter (1960 pp. 141 ff.).

Hiltner (1930) and others have emphasized the *importance of dew* for the water economy of plants. Wahlin (1943 p. 355) considers that dew (1) increases the soil water content, (2) provides an opportunity for water absorption above ground and (3) decreases the transpiration loss. He also presented a curve for the diurnal water deficit (as % of maximum water content) for *Arrhenatherum elatius* in an alvar area on Stora Karlsö.

An important work in this field was carried out by Arvidsson (1951) with the Alvar vegetation as her main object. Some of her results are summarized below: In a situation of water deficit the leaves become wilted or curled, the latter mostly in dry habitats. Longer dry periods produced curled leaves, e.g. in *Filipendula vulgaris* and *Fragaria viridis*. The leaves, if still alive, mostly spread out again when the drought was over.

A higher *drought resistance* was found in alvar species than in plants of communities subjected to other habitat conditions (e.g. forest, meadow, and sea-shore vegetation). Natural water deficit values for alvar species showed equal or even higher figures than were known from extremely dry areas, such as African deserts and Mediterranean macchia vegetation.

In early summer dew occurs on plants only for a short period (3—4 hours) diurnally. According to Arvidsson, the earlier loss of water by transpiration is then compensated by absorption. In late summer dew remains on the plants 2—3 times as long. Nocturnal absorption may then exceed the transpiration loss, even when this loss has caused very low water deficit values.

However, rain plays a more important role. A decrease up to 50% of the water deficit was shown to take place by rain absorption, being most effective in afternoons and during nights. On Öland the ability of plants to absorb water from mist through leaves and other above-ground organs appears to be well developed. Finally, it was considered that direct absorption of water from dew, mist or rain could diminish the negative effect on alvar vegetation during prolonged aestival drought periods.

The *effect of windspeed* on the growth of plants has been reported on in many papers, e.g. Russel & Grace (1979 pp. 507 ff.), who measured the effect of windspeed on *Lolium perenne* and *Festuca arundinacea* in a wind-tunnel at four constant velocities (1.1, 4.0, 7.4, and 10.0 m/s) for a period of 14 days.

It was found that plants exposed to high windspeeds became shorter and had fewer leaves in comparison with those exposed to lower speeds. Damage to the leaves increased with windspeed and became more pronounced on older leaves. "The mean relative growth rate of the whole plant, of the aboveground parts, and of leaf area all tended to decline with increasing windspeed" (op. cit. p. 501).

Russel & Grace also considered water stress to be important for the reduced growth in wind, although reduction in growth could also take place without water stress. The net photosynthetic rate per unit weight also seemed to decrease, being a result of the increased proportion of non-assimilatory tissue in these leaves. Several studies have demonstrated that plants exposed to wind have a larger amount of structural tissue. It has also been

suggested that the cell expansion is affected (op. cit. p. 513).

These results are in good accordance with the above-mentioned information on alvar plants given by Witte (1906c). The reduction due to wind-speed, experienced with regard to the grasses in these experiments, is therefore most likely also found in the vegetation of the Alvar which is permanently exposed to fairly strong winds.

Pettersson (1958 pp. 202 ff.) discussed dwarf growth and prostrate forms of several taxa found on Gotland. He gave a broad review of such phenomena mainly according to Johansson (1897) and Witte (1906a, b) but also based on his own experience. Several of the same taxa are found on Öland. Among shrubs, he mentions *Juniperus communis, Prunus spinosa,* and *Cotoneaster integerrimus* which appear in prostrate forms, also without grazing impact. The same phenomenon was found by the present author on the Stora Alvaret.

A special feature is the ability of *Agrostis stolonifera* to form *very long stolons* (up to 20 cm) during wet conditions. These stolons, after having established adventitious roots, form new individuals relatively far away from the mature mother plant. In this way *Agrostis* could be strongly competitive to *Festuca ovina.* However, in the long run, *Festuca ovina* seems again to be the stronger in the competition. Frozen tufts of *Festuca ovina* (within ice) may become lifted and totally separated from the ground during extreme conditions but have been observed to settle down and to start growing in the spring.

Many taxa have *a second flowering* after the dry period (often very dry) in the middle part of the summer. Late summer and early autumn are climatically favourable for re-florescence. Taxa such as *Helianthemum nummularium, Prunella grandiflora, Anthyllis vulneraria,* and *Lotus corniculatus* can be seen with flowers in September—October and later. Sterner repeatedly found *Thymus serpyllum, Sedum album, S. reflexum,* and *Oxytropis campestris* with flowers even in late December (1948 p. 105).

3 Standing crop and dynamics in permanent sample plots

The intention of this main part of the project was to estimate the biomass available for grazing on the Alvar during the grazing season (6 months). At the same time, records of the plant cover and its composition were to be made.

It was also decided that these investigations should only concern the two most important plant communities for grazing, namely the *Avenetum* and the *Festucetum*. By experience we knew these were preferred by sheep to other plant communities.

The aim of the investigations in the *Avenetum* and the *Festucetum* was to reflect possible differences between areas with or without sheep grazing. In most of the areas without sheep grazing an irregular grazing with low intensity by heifers took place.

3.1 Methods

To carry out the investigations suggested, a system of permanent plots was designed. Most of these plots were intended to reflect the ungrazed phase, so to obtain the undisturbed production of the *Avenetum* and the *Festucetum* in the Stora Alvaret. A smaller number should reflect the situation in areas where vegetation was already more or less transformed by sheep grazing. In the latter plots it was of interest to compare differences between areas still grazed and areas which were to be protected by enclosures from further grazing. The sample plots numbered 60 in all, an acceptable number with regard to the time available for the annually repeated investigations. They were distributed as follows.

Avenetum		*Festucetum*	
grazed, fenced	5	grazed, fenced	5
grazed, unfenced	5	grazed, unfenced	5
ungrazed, fenced	20	ungrazed, fenced	20

To fulfil the criterium of sheep-grazed vegetation it was necessary to find out where uninterrupted grazing could be expected during the planned period of investigation (1969—72). Difficulties were encountered as some of the larger sheep farming companies had economic problems at that time. Areas where no sheep grazing was expected to be started were easier to find as some large alvar areas were already temporarily protected by law (cf. Chapter 1).

To obtain an estimate of the average production on the Stora Alvaret it was necessary to spread the research areas to ensure that differences in production due to local variations were not missed. In these subjectively selected local areas of the Alvar, subareas of typical and homogeneous *Avenetum* and *Festucetum* respectively, ungrazed or grazed, were mapped. All these subareas were numbered within each selected research area, and then one or two of these subareas were chosen at random. In that way both low- and high-productive types of each plant association might be represented.

In the subareas, plots were subjectively laid out in homogeneous spots, two and two. Such a sample plot included two quadrats, i.e., a test plot (A) and a control plot (B), each with a size of 1 m^2. These sample plots were permanently marked out with aluminium and plastic sticks. All plots were enclosed, except for the 10 intended to be influenced by further grazing. In areas grazed by sheep the enclosures consisted of wire netting but in ungrazed (or cattle grazed) a barbed-wire fence was used. The fence gave a zone of 0.5 m around the plots, preventing animals from reaching and grazing the plot. Erecting the fences was complicated in areas with thin soils, and boards had to be used to support the fences (Fig. 6).

3.1.1 Documentation of the sample plots

Each year in July the plots were vertically photographed with a Hasselblad camera (500 C). From the second year onwards a wide angle lens could be used. Black and

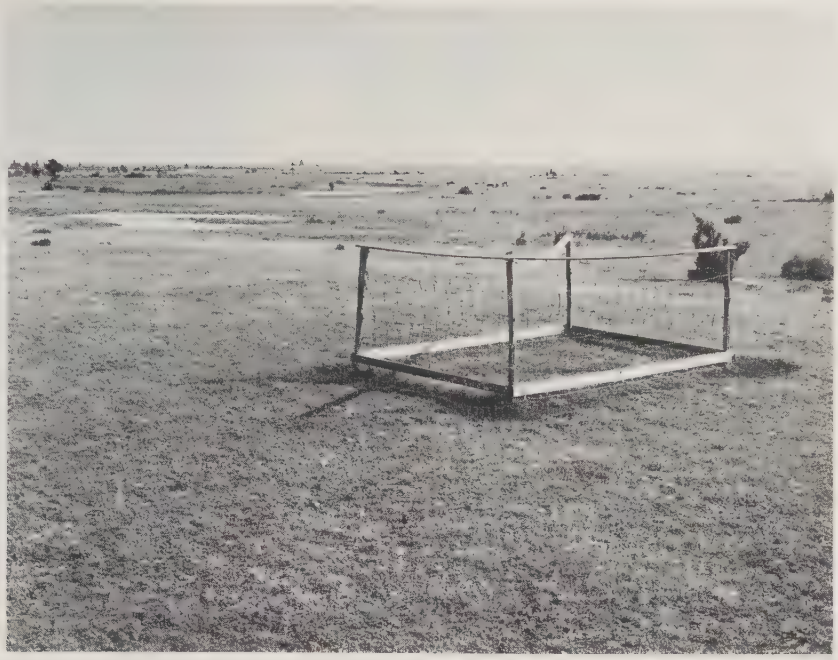


Fig. 6. Enclosed permanent sample plot in *Avenetum*-area grazed by sheep. When sheep-grazed this vegetation is characterized by a low sward and few junipers. Herbids (in prostrate forms) are more dominant than graminids. In areas with thin soils, boards had to be used to support the fences. — Alvar of Kleva. 16 August 1972.

white film was used. Additional slides were taken with another camera. To show the limits of the plots a frame of plastic line was hooked onto the permanent aluminium and plastic markers. A small board with plot data provided information on the photo and facilitated later identification.

After photo-documentation qualitative and quantitative records of taxa were made in each plot. For estimation of cover the 5 degree scale of Hult-Sernander-Du Rietz was used, with addition of an "x" value, as follows: Vertical projection covering 1/1—1/2 = 5, 1/2—1/4 = 4, 1/4—1/8 = 3, 1/8—1/16 = 2, less than 1/16 = 1, single and small specimens = x.

The "x" value was mainly used for annuals such as a *Linum catharticum, Myosotis stricta*, or for small seedlings of other taxa. For one single fairly large specimen, e.g., of *Filipendula vulgaris* the value "1" was used.

To estimate the production during the season it was decided to take two harvests every year in the permanent test plots. One harvest, taking 3—4 weeks, was taken in late July to early August and the other in November, representing the summer and the autumn production. The summer cut was taken at that late stage to avoid the bare plots being fully exposed to high insolation and drought, which usually occur in July. Test plots were planned to be harvested during a 4-year period. In that way an influence of very hard "simulated grazing" was expected to appear.

The control plots in four sample plots (1, 2, 7, 8) were neglected in order to increase the total number of test plots that could be treated, this modification to the experimental plan being decided before the first harvest.

3.1.2 Harvest and recording modifications

After the first harvest-year a modification of the harvesting plan was made as it was considered of great interest to observe the development if some parts of the test plot were allowed to recover for a period of years in comparison with those cut in all 4 years. In that way various degrees of influence were obtained which could be compared in the last year of harvest (1972). To allow year-to-year comparisons with non-treated plots, the schedule had to be modified. The new schedule was a compromise showing the effect of the harvest in the last year without greatly increasing the number of recorded subplots. Totally accomplished records of all subplots would of course have been interesting, but it would have required too

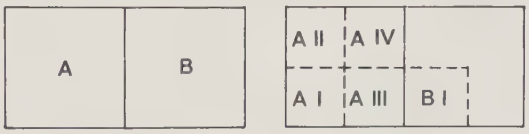


Fig. 7. Lay-out of permanent sample plots, which consists of a test plot (A) and a control plot (B), each with a size of 1 m^2. The test plot was divided into four subplots (A I—A IV). One subplot (B I) was used in the control plot.

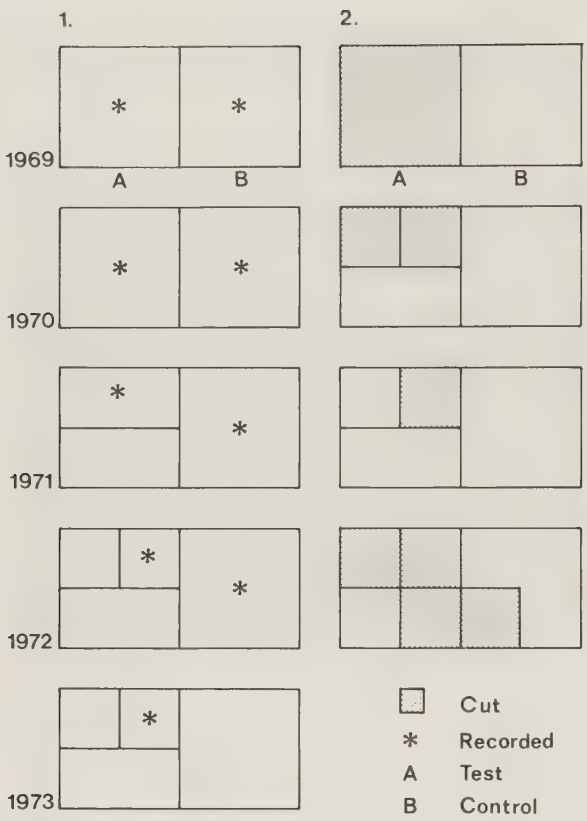


Fig. 8. Plan for recording the taxa (1) and harvesting (2) during 1969—73 in permanent sample plots (2 x 1 m^2). Records of plots presented in tables in the text are shown (other subplots were also recorded but are not included here). The test plot was cut twice a year (July/August and November).

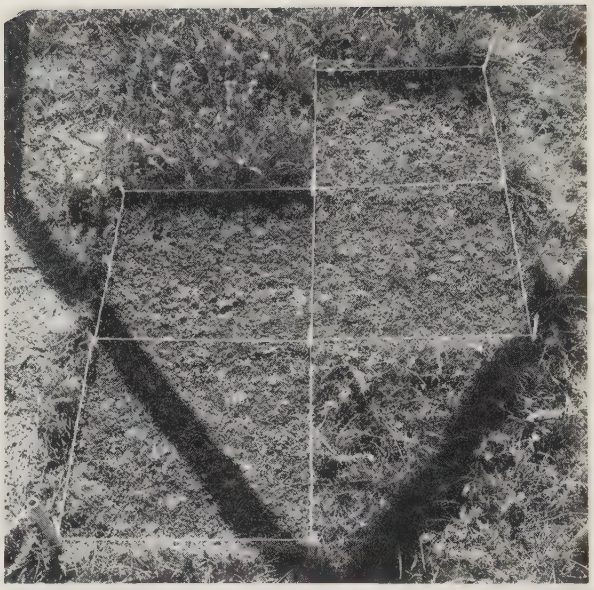


Fig. 9. Permanent sample plot in ungrazed *Avenetum* vegetation. Subplots (50 x 50 cm) which were harvested different numbers of years were cut in 1972 and compared. *Arrhenatherum pratense, Filipendula vulgaris, Plantago lanceolata,* and *Anemone pratensis* may be distinguished in uncut parts. — Alvar of Nedre Ålebäck. 16 August 1972.

much time. The schedules for harvests, records, and plot numbers, are given in Figs. 7 and 8.

In 1972 it was necessary to get a new reference value of ungrazed vegetation for two reasons: (1) for comparison with the various harvested subplots, (2) to give a measure of undisturbed production that year, which was high compared with that of 1969. Consequently part (BI) of the control plots was cut.

These modifications changed the sizes of the plots (both cut and recorded), and thus it is not fully statistically correct to compare them from one year to another. Nevertheless, the modification was considered sufficiently important to make, despite the additional risk of increasing the border effect in the subplots.

There is also a risk that the changed size of the plots will give a different interpretation of the cover values. For example, a specimen in a larger plot gets a cover of "1", but in a smaller plot it occupies a relatively larger area and thus might receive a "2" in the cover scale.

In addition, the reduction in the cut area during 1970—71 saved considerable amounts of time (the harvest of a 1/4 m^2 plot in *Festucetum* took about 1/2 hour but 1—2 hours for *Avenetum*).

The plants were cut with an ordinary pair of scissors. All higher vegetation was removed as close as 2 mm above the ground, if possible not damaging the possibility for regeneration. The cut area was limited by the vertical projection of the frame of plastic line mentioned earlier, which means that leaves stretching into the plot from a plant growing outside were collected. Correspondingly, parts of a plant growing inside the plot but projecting outside the strings were not collected (Fig. 9).

Mosses and lichens have little or no importance for grazing, and they were left in the plots as intact as possible so as to avoid changing the composition unnecessarily. Removal could create bare soil patches where, e.g., annuals rapidly could colonize. After the first harvest-year it was found that some taxa had to be cut in a certain way in order to let them survive, e.g., on dwarf shrubs (*Helianthemum, Thymus, Calluna*) a small part of the stem was spared to give new shoots.

Harvested material from the plots was collected in plastic bags. Soil, lichens, mosses, and litter were removed before the crop was dried for 24 hours at 80°C and weighed.

3.1.3 Separation of standing crop

In connection with the modified cuts it was also important to separate the standing crop into three components: graminids, herbids, and dwarf shrubs, which was done in 1970 and 1972. The intention was to find any differences in composition of the vegetation of these three groups due to the various treatments. Only a representative part of the total material was sorted on all occasions, as this work is extremely time-consuming.

In 1972, which was a very productive year, with a large amount of biomass to harvest, it was realized after a few cuts that it would be impossible to harvest all subplots, even though I had some assistance that year. A reduction had to be made. A random schedule was created showing the plots which preferably should be cut and sorted.

During the summer 199 subplots (80%) of 248, and in the autumn 137 (55%) of 248 were harvested, of which 154 subplots (62%) and 109 (44%) respectively were sorted (see Appendix 1).

In the two subplots harvested for the longest period, 3 and 4 years, the records were continued until 1973—75 to study the expected recovery. In nine control plots, not harvested in 1972, yearly records have been continued until the time of writing in 1981 (Tables 19 and 20).

3.2 Results

3.2.1 Standing crop

An accurate estimate of the production of an area is very difficult to make as there are many ecological factors involved (in addition to grazing influence). From the normal situation, aberrant climatic conditions within or between years will favour or depress different plants or groups of plants for part of the growth period, for the following year or for a number of years. Thus, such estimations of production are very hazardous if they rely on a short period of investigation when the total result might depend on an abnormal year within or before the period concerned.

Table 7. Standing crop for ungrazed vegetation in a low productive year (1969) and a high productive year (1972). Weights in g/m^2 rounded off to the closest integer.

	1969	1972	Difference (%)	Mean value
Avenetum	295	344	17	320
Festucetum	133	146	10	140

This became clear from the very beginning of this investigation on the Stora Alvaret, as the first year (1969) was extremely dry during the summer months. This first year could be expected to show lower values than an average year, as can be seen in comparison with the highly productive year of 1972. In 1972 the *Avenetum* values for ungrazed vegetation were 17% higher and those for *Festucetum* 10% higher than in 1969. The figures in Table 7 are calculated from the combined values of the summer and autumn standing crops, without any corrections.

The figures obtained show that it was necessary to cut part (BI) of the control plots in 1972. In that way mean values of these two years are probably closer to the normal production values, and better than any of these years separately.

In comparison, a mean value of 336.5 g/m^2 for a dry meadow vegetation on a beach ridge on Öland, similar to that of the *Avenetum* on the Alvar, was obtained by Ammar (1978 p. 59).

Production values from the six types of harvested sample plots are presented in Table 8, showing that the cutting caused increasing wear from 1969 to 1972. There is a considerable decrease from 1969 to 1970 in all types, and furthermore a small decrease to 1971 (with two exceptions in the *Festucetum*). In 1972 there is, in contrast, an increase, but not in the *Festucetum* which still decreases (Plate 2:5—8). The values from the 1969 harvest may be compared with the values from the control plots (BI) in 1972, harvested for the first time. As expected, the values for grazed-unfenced *Avenetum* are lower than for grazed-fenced and ungrazed plots (1969—72). The same applies to the *Festucetum*, the initial value (1969) not included.

Comparing *Avenetum (A.)* and *Festucetum (F.)*, the losses of standing crop are larger in *F.* than in *A.* which can be seen in the percentage values. These calculations assumed that the total produc-

Table 8. Yearly standing crop (g/m^2) for Avenetum and Festucetum vegetation (grazed or ungrazed), summer, autumn and total crops, 1969–72. Figures obtained from permenent plots (fenced or unfenced) cut different numbers of times (cf. Fig. 8). Percentage change in total standing crop (with year 1969 as 100 %) is given. Harvest in July/August and in November.

	AVENETUM					FESTUCETUM				
Year	1969	1970	1971	1972	1972	1969	1970	1971	1972	1972
Cut subplot(s)	AI-IV	AII+IV	AIV	AIV	BI	AI-IV	AII+IV	AIV	AIV	BI
No. of years cut	1	2	3	4	1	1	2	3	4	1
Grazed, fenced										
Summer	134	101	101	106	300	133	31	39	15	127
Autumn	42	29	15	35	91	7	15	9	15	24
Total	176	131	116	141	391	141	46	48	30	152
Percent	100	74	66	80	222	100	33	34	21	108
Grazed, unfenced										
Summer	120	80	70	77	142	131	18	24	11	118
Autumn	34	22	14	25	41	6	12	8	13	26
Total	155	103	84	103	183	137	31	33	23	144
Percent	100	66	54	66	118	100	23	24	17	105
Ungrazed, fenced										
Summer	242	102	88	107	289	123	30	26	18	123
Autumn	53	40	21	35	55	10	12	7	9	24
Total	295	142	108	142	344	133	42	33	27	146
Percent	100	48	37	48	117	100	32	25	20	110

tion in 1969 in each type was 100 percent. In the *F.* only the unfenced plots differ, which could be referred to the combined effect of removal by grazing and by harvest. The grazed-unfenced *A.* plots have lower values than those of the grazed-fenced *A.*, for the same reason.

Within the *Avenetum* there is a large difference between grazed and ungrazed plots, where the latter have much lower values. This indicates that there is an adaptation to removal of the crop in the *Avenetum*, which has taken place in the vegetation already grazed, but not in the plot suddenly disturbed by harvest. The higher initial value in ungrazed *A.* (295) includes some necromass mostly from the previous years production. Lower amounts of necromass are included in the grazed areas, which therefore give lower values of standing crop. In this respect, it is interesting to note the exceptionally high value for the BI-plots (part of control plots) in grazed *A.* (1972), which have been enclosed for 4 years. This high value is probably due to a combination of a recovery effect in the vegetation, when sheltered against further grazing, and a fertilization effect caused by droppings remaining from the beginning of the investigation. Collected attached necromass (possibly also including small amounts of litter) and stimulated growth by poor light conditions in the thick sward may be parts of the explanation.

When an earlier grazed area is fenced to avoid further grazing, a dynamic situation occurs and a recovery of the field layer will take place. This is very obvious for the *Avenetum*, as seen above. The same is not found in the values of the *Festucetum*. Grazed unfenced areas maintain a less dynamic situation (temporary stabilization) as long as grazing is continued at the same level. In these plots it is possible to find changes related to climatic differences from one year to another. In ungrazed fenced plots no rapid changes take place as this vegetation is adapted over a long period of time, resulting in a certain level of stability. Climatically induced changes are seen.

Table 9. Standing crop for grazed vegetation in a low productive year (1969) and a high productive year (1972). Weights in g/m^2 rounded off to the closest integer. (c - estimated)

	1969	1972	Difference (%)	Mean value
Avenetum	176	208 c	18 c	192 c
Festucetum	141	152	8	147

Mean values of standing crop for ungrazed areas are shown in Table 7. For the standing crop on the grazed areas the estimations is not as easy. Ideally, the values should be based on fenced plots. For the *Festucetum*, with no pronounced changes, it was possible to calculate a mean value, but for the *Avenetum* the exceptionally high value interferes with the calculation.

Ungrazed and grazed unfenced standing crops are 17% and 18% higher respectively in 1972 than in 1969. If 18% is added to the 1969 value for

Table 10. Summer and autumn crops in percent of total standing crop for Avenetum and Festucetum from 1969 to 1972, with increased number of cuttings in permanent plots (cf. Tab. 8). Harvest in July/August and in November.

	AVENETUM					FESTUCETUM				
Year	1969	1970	1971	1972	1972	1969	1970	1971	1972	1972
Cut subplot(s)	AI-AIV	AII+IV	AIV	AIV	BI	AI-IV	AII+IV	AIV	AIV	BI
No. of years cut	1	2	3	4	1	1	2	3	4	1
Grazed, fenced										
Summer	76	78	87	75	77	95	68	81	51	84
Autumn	24	22	13	25	23	5	32	19	49	16
Grazed, unfenced										
Summer	78	78	83	75	78	96	60	75	45	82
Autumn	22	22	17	25	22	4	40	25	55	18
Ungrazed, fenced										
Summer	82	72	81	75	84	93	71	78	67	84
Autumn	18	28	19	25	16	7	29	22	33	16

grazed fenced *Avenetum* an estimated value is received for 1972. Values for grazed *Avenetum* and *Festucetum* are shown in Table 9.

In this connection, the following comments must be made. The mean value for *F.* (147) is based on values from plots in areas with higher average productivity than *F.* in general on the Alvar. Thus, it is too high, as is realized when compared with that of ungrazed *F.*, which reaches only 140.

The figures given in Table 8 must be considered from various aspects to find possible explanations of the differences. In Table 10 the percentage figures are shown for summer and autumn crops, year by year, for the six types of sample plots. In the case of the *Avenetum*, there is a very high similarity between the years for grazed-fenced, grazed-unfenced and ungrazed-fenced plots. There is a pronounced difference between summer and autumn production in the 1971 figures in all three types of plots, but there is also a difference for the BI-plots and those of 1969 in ungrazed *A.* Nevertheless, between themselves these diverging figures show similar proportions. In 1971 the dry periods in July and September—October caused a low crop in the autumn, thus giving the summer crop a higher percentage. The higher summer values of the BI-plots and in 1969 for ungrazed *A.* are probably due to the very changed conditions connected with the drastic removal of the standing crop (in the unadapted vegetation) and with the necromass involved.

In the *Festucetum* there is another situation. In the first year (1969) the highest values (93—96%) of summer crops are found on all three types of plots. The very severe drought that summer probably killed much of the vegetation on these thin soils, consisting of several taxa with low ability to store water. Consequently, the production in the autumn became very small in connection with the considerable removal of crops.

In the BI-plots there is a similar proportion but not so pronounced as in 1969, as there was a high production in the autumn. Considering all types of *F.* plots, the longer the period during which they have been cut, the more pronounced is the change from summer to autumn production. The year 1971 is different as regards the low autumn production, as mentioned before. In the crops of 1970 and 1972 the autumn part is very large. Unfenced *F.* plots (1972) also show the highest values in the autumn (55%), probably to some extent due to the removal by grazing during the summer. These changed proportions may be explained partly by harvest damage to the grass tufts of the *Festucetum*. Such damage exposes the remaining parts to heavy rains, and most of all, gives the tufts poor resistance towards frost-induced soil movements during periods with water-saturated soil and temperatures around 0°C. (Such soil movements were also observed in heavily grazed *Avenetum* areas as well as in the most heavily cut plots in the *A.*). The soil surface structure of these plots in the *Festucetum* was continuously changing, causing the grasses difficulties in recovering or recolonizing. Recolonization sometimes succeeded at the margins of the formed polygons, where soil was more stabilized than in other parts of the plot (cf. Fig. 10). In spring or early summer the soil in the harvested plots remained more raised than in the control plots as a result of these movements, until a heavy rain pressed it down again (cf. Fig. 11). If not

Fig. 10. Frost-induced soil movements, forming polygons with sorted material, are frequently found on thin weathering soils that are poorly drained. Colonization of plants takes place at the margins of the polygons where the soil is more stabilized than in other parts. Such frost-induced movements increased in plots which were cut several times during the period of investigation. — Alvar of Gynge. 5 May 1974.

Fig. 11. Fine calcareous material becomes raised by frost-induced soil movements in places with bad drainage and loose vegetation cover. These areas easily get eroded by, e.g., trampling and wind if the soil dries out before being compacted by rain. — Alvar of Gynge. 5 May 1974.

Table 11. Standing crop for Avenetum and Festucetum vegetation (grazed or ungrazed) in 1972, summer and autumn crops, and related to repeated "wear" by cutting in permanent plots. Harvests in August and in November.

	AVENETUM				FESTUCETUM			
Cut subplot	BI	AIII	AII	AIV	BI	AIII	AII	AIV
No. of years cut	1	2	3	4	1	2	3	4
Grazed, fenced								
Summer	300	214	143	106	127	92	49	15
Autumn	91	76	48	35	24	29	17	15
Total	391	290	191	141	152	121	66	30
Grazed, unfenced								
Summer	142	118	87	77	118	53	26	11
Autumn	41	37	35	25	26	25	16	13
Total	183	155	122	103	144	78	42	23
Ungrazed, fenced								
Summer	289	253	180	107	123	90	41	18
Autumn	55	60	50	35	24	23	13	9
Total	344	314	229	142	146	114	54	27

Table 12. Summer and autumn crops in percent of total standing crop for Avenetum and Festucetum in 1972, with increased number of cuttings in permanent plots (cf. Tab. 10). Harvest in August and in November.

	AVENETUM				FESTUCETUM			
Cut subplot	BI	AIII	AII	AIV	BI	AIII	AII	AIV
No. of years cut	1	2	3	4	1	2	3	4
Grazed, fenced								
Summer	77	74	75	75	84	76	74	51
Autumn	23	26	25	25	16	24	26	49
Grazed, unfenced								
Summer	78	76	71	75	82	68	61	45
Autumn	22	24	29	25	18	32	39	55
Ungrazed, fenced								
Summer	84	81	78	75	84	79	76	67
Autumn	16	19	22	25	16	21	24	33

pressed down, the drought influence increased in the loose soil, furthermore increasing due to the less shelter given by the decreasing vegetation cover. These conditions created a very unfavourable situation for recovery. During late summer and autumn the situation was more stabilized with more water available, thus providing an opportunity for production.

Table 11 contains results from the final harvest in 1972 of the different treatments. The Table shows increasing values of standing crop with a prolonged period of regeneration for the plots. In the *Avenetum*, the plots harvested for 2 years (A III) have reached the 1969 values (155) in grazed-unfenced, and have even passed the 1969 values in the other two types (cf. Table 8). Also in AII (cut for 3 years) in grazed-fenced plots the 1972 value has past that of 1969. It is interesting to note that AIV in grazed-fenced and ungrazed-fenced *Avenetum* show almost identical figures, possibly being adapted in the same way.

In the *Festucetum*, the 1972 values have not reached those of 1969 in any of the three types of sample plots, except for BI plots. For both grazed-fenced and ungrazed-fenced plots there are similarites in level of recovery for *A.* and *F.* respectively, while lower figures are shown for grazed-unfenced *A.* and *F.*

The percentage proportions between summer and autumn crops for the 4 stages of harvest "wear" in all 6 types of sample plots are shown in Table 12. Values obtained appear remarkably regular in the *Avenetum*, with about 3/4 of the production in the summer and 1/4 in the autumn even if they are harvested for two years or more. In the ungrazed *A.* there are two exceptions in AIII and BI with somewhat higher summer values. They might not have had sufficient time to adapt to the effect of harvest or grazing. This Table shows similarities with *A.* in Table 10, with similar "wear", but partly in other plots.

For *Festucetum* in Table 12 there is another situation than for the *Avenetum*. The longer the interval between harvests the larger the part of the crop obtained in the summer harvest, as the tufts were able to regenerate. This trend can be seen clearly in ungrazed-fenced and grazed-fenced *Festucetum*. The trend is the same in unfenced areas,

Table 13. Summer, autumn and total standing crop (g/m^2) in 1972 for graminids, herbids, and dwarf shrubs in permanent plots with different previous wear in grazed-fenced or unfenced or ungrazed-fenced Avenetum and Festucetum vegetation on the Stora Alvaret (a). Percentage of summer and autumn crop within total standing crop for each category and type of subplot (b). Percentage of each categ within summer, autumn and total standing crop for each type of subplot (c). Harvest in August and in November 1972. (G = grazed, UG = ungrazed, F = fe UF unfenced).

	AVENETUM												FESTUCETUM											
	Graminids				Herbids				Dwarf shrubs				Graminids				Herbids				Dwarf shrubs			
Cut subplot	BI	AIII	AII	AIV	BI	AIII	AII	AIV	BI	AIII	AII	AIV	BI	AIII	AII	AIV	BI	AIII	AII	AIV	BI	AIII	AII	
No. of years cut	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	
Grazed, fenced																								
(a) Summer	154.6	110.4	58.4	31.1	139.5	98.5	75.4	70.3	6.3	9.8	8.9	4.5	110.7	84.6	43.4	12.6	12.9	4.8	3.5	2.3	6.6	2.5	1.8	
Autumn	43.7	38.7	20.6	14.8	46.3	36.4	26.4	19.9	0.5	0.9	0.8	0.4	22.3	27.4	18.1	13.0	1.2	1.5	1.6	1.3	0.8	0.3	0.4	
Total	198.3	149.1	79.0	45.8	185.8	134.9	101.8	90.2	6.8	10.6	9.6	5.0	133.0	111.9	61.5	25.6	14.2	6.4	5.1	3.6	7.4	2.8	2.2	
(b) Summer	78	74	74	68	75	73	74	78	92	92	92	91	83	76	71	49	91	76	69	64	89	89	80	
Autumn	22	26	26	32	25	27	26	22	8	8	8	9	17	24	29	51	9	24	31	36	11	11	20	
(c) Summer	51	50	41	29	46	45	53	66	2	4	6	4	85	92	89	84	10	5	7	15	5	3	4	
Autumn	48	51	43	42	51	48	55	57	1	1	2	1	92	94	90	90	5	5	8	9	3	1	2	
Total	51	51	41	33	48	46	53	64	2	4	5	4	86	92	89	87	9	5	7	12	5	2	3	
Grazed, unfenced																								
(a) Summer	64.7	69.6	40.4	21.3	61.5	42.8	42.4	51.4	15.9	5.3	4.4	4.4	114.6	50.6	24.3	7.6	2.3	1.8	1.4	3.4	1.3	0.4	0.04	
Autumn	22.9	26.2	23.0	14.0	17.0	10.3	11.6	10.9	1.2	0.7	0.4	0.5	25.2	23.9	15.4	11.7	0.4	0.7	0.7	1.1	0.2	0.2	0.04	
Total	87.6	95.8	63.4	35.2	78.5	53.0	54.0	62.3	17.1	6.0	4.8	5.0	139.8	74.4	39.7	19.4	2.6	2.5	2.1	4.4	1.6	0.6	0.1	
(b) Summer	74	73	64	60	78	81	79	83	93	89	92	90	82	68	61	39	86	73	67	76	85	62	50	
Autumn	26	27	36	40	22	19	21	17	7	11	8	10	18	32	39	61	14	27	33	24	15	37	50	
(c) Summer	46	59	46	28	43	36	47	67	11	5	5	6	97	96	94	65	2	3	5	29	1	1	0	
Autumn	56	70	66	55	41	28	33	43	3	2	1	2	98	96	96	91	2	3	4	8	1	1	0	
Total	48	62	52	34	43	34	44	61	9	4	4	5	97	96	95	79	2	3	5	18	1	1	0	
Ungrazed, fenced																								
(a) Summer	167.5	133.4	65.6	31.3	72.7	105.0	100.8	78.2	35.0	15.6	15.0	4.2	111.8	91.0	37.4	14.7	10.8	4.3	4.7	3.6	10.0	9.6	2.1	
Autumn	35.0	29.9	17.2	10.9	18.7	29.8	32.4	22.7	3.0	3.2	1.0	0.7	22.7	21.7	12.5	8.3	0.9	0.6	0.7	1.3	0.6	0.9	0.3	
Total	202.5	163.4	82.8	42.2	91.4	134.8	133.2	101.0	38.0	18.8	16.0	4.9	134,4	112.7	49.8	23.0	11.7	4.9	5.4	4.9	10.6	10.4	2.4	
(b) Summer	83	82	79	74	80	78	76	77	92	83	94	85	83	81	75	64	92	89	87	74	94	92	88	
Autumn	17	18	21	26	20	22	24	23	8	17	7	15	17	19	25	36	8	11	13	26	6	8	12	
(c) Summer	61	53	36	28	26	41	56	69	13	6	8	4	84	87	85	77	8	4	11	19	8	9	5	
Autumn	62	48	34	32	33	47	64	66	5	5	2	2	94	94	93	86	4	2	5	13	2	4	2	
Total	61	52	36	29	28	43	57	68	11	6	7	3	86	88	87	80	7	4	9	17	7	8	4	

Table 14. Standing crop in three plant categories (graminids, herbids and dwarf shrubs) from summer, autumn and total crops in 1970 and 1972. Plots subjected to repeated "wear" by cutting (cf. Fig. 8). Harvest in July/August and November.

	AVENETUM									FESTUCETUM								
	Graminids			Herbids			Dwarf shrubs			Graminids			Herbids			Dwarf shrubs		
Year	1972	1970	1972	1972	1970	1972	1972	1970	1972	1972	1970	1972	1972	1970	1972	1972	1970	
Subplot(s)	BI	AII+IV	AIV	BI	AII+IV	AIV	BI	AII+IV	AIV	BI	AII+AIV	AIV	BI	AII+AIV	AIV	BI	AII+AIV	
No. of years cut	1	2	4	1	2	4	1	2	4	1	2	4	1	2	4	1	2	
Grazed, fenced																		
Summer	154.6	17.8	31.1	139.5	79.0	70.3	6.3	4.5	4.5	110.7	20.5	12.6	12.9	9.9	2.3	6.6	0.7	
Autumn	43.7	6.3	14.8	46.3	22.3	19.9	0.5	1.0	0.4	22.3	12.1	13.0	1.2	2.8	1.3	0.8	0.4	
Total	198.3	24.1	45.8	185.8	101.2	90.2	6.8	5.5	5.0	133.0	32.6	25.6	14.2	12.7	3.6	7.4	1.1	
Percent	51	18	33	48	77	64	2	4	4	86	70	87	9	27	12	5	2	
Grazed, unfenced																		
Summer	64.7	16.6	21.3	61.5	60.1	51.4	15.9	3.5	4.4	114.6	16.4	7.6	2.3	1.7	3.4	1.3	0.2	
Autumn	22.9	6.3	14.0	17.0	16.9	10.9	1.2	0.5	0.5	25.2	12.7	11.7	0.4	1.9	1.1	0.2	0.5	
Total	87.6	22.9	35.2	78.5	77.0	62.3	17.1	4.0	5.0	139.8	29.2	19.4	2.6	3.6	4.4	1.6	0.7	
Percent	48	22	34	43	74	61	9	4	5	97	87	79	2	11	18	1	2	
Ungrazed, fenced																		
Summer	167.5	33.1	31.3	72.7	63.0	78.2	35.0	5.5	4.2	111.8	22.2	14.7	10.8	6.2	3.6	10.0	1.3	
Autumn	35.0	14.2	10.9	18.7	23.8	22.7	3.0	0.8	0.7	22.7	11.0	8.3	0.9	1.1	1.3	0.6	0.1	
Total	202.5	47.3	42.2	91.4	86.9	101.0	38.0	6.3	4.9	134.4	33.1	23.0	11.7	7.3	4.9	10.6	1.4	
Percent	61	34	29	28	62	68	11	4	3	86	79	80	7	18	17	7	3	

but here the grazing gives still lower figures of summer production.

In 1972 separation into three components, graminids, herbids, and dwarf shrubs, was carried out for standing crop in summer and in autumn, and for all stages of wear (Table 13). Considering the figures for dwarf shrubs in plots harvested 3—4 years, they show very low weight values, consequently giving a large variation in percentage, even with small differences in amounts. This would happen if a branch of, e.g., *Thymus* entered the plot from outside, which occurred in a few plots, giving confusing variations in percentage, which do not fit into the trends obtained. The figures are

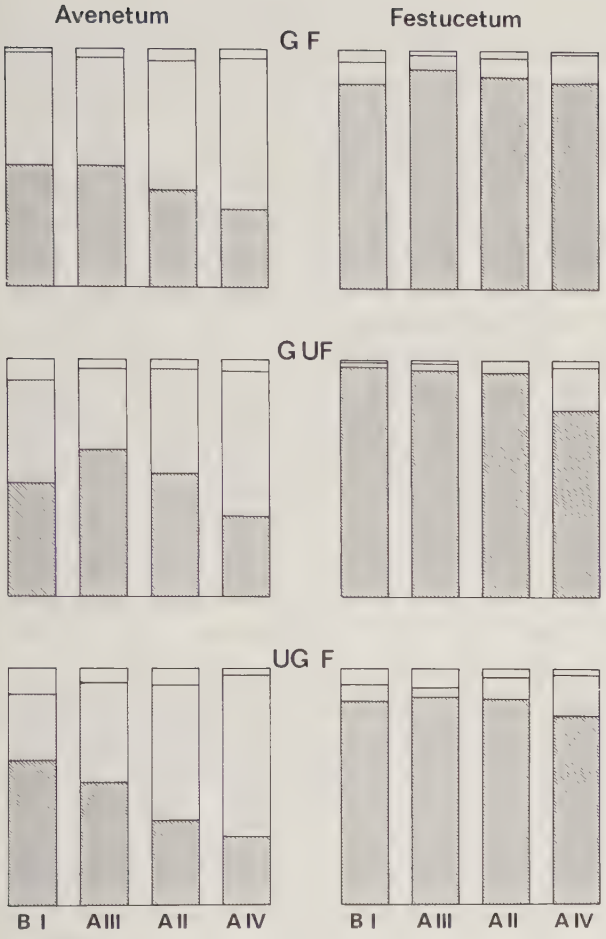


Fig. 12. Percentage content of graminids, herbids, and dwarf shrubs in grazed fenced (GF), grazed unfenced (G UF) and ungrazed fenced (UG F) sample plots in the *Avenetum* and *Festucetum* vegetation in 1972. (Diagonal shading = graminids, dotted = herbids, unshaded = dwarf shrubs; no. of years cut: B I = 1 year, A III = 2, A II = 3, and A IV = 4). Percentage values are given in Table 13.

usually calculated from a somewhat larger number of plots cut in summer than in autumn (cf. Appendix 1). The mean values of these are combined.

Regarding the *Festucetum* in Table 13, there is an indication that the proportion of the autumn crop increased the longer the period that the subplots were harvested. This applies to all the three components, but with a few exceptions. For dwarf shrubs in ungrazed *Festucetum* the summer production is higher in all subplots, but in the grazed *F.* they seem to have a rather large production in some plots in the autumn. This might be explained by the lower amount of dwarf shrubs from the start in the grazed areas, and also since even small changes within a small amount may change the percentage considerably.

The percentage content of each of the 3 components in the total crop from the various subplots shows a weak decrease for graminids and dwarf shrubs, but an increase for herbids with an increased number of harvests in the *F.*, probably due to the possibility for annual herbids to increase rapidly when competition of graminids and dwarf shrubs is decreased and more bare soil is available for colonization. In autumn, wintering hapaxants play an important role in the production of herbids.

In the *Avenetum* the proportion of graminids is decreasing in the summer crop and increasing in the autumn crop with increased number of harvests in the subplots. The herbids seem to have about the same proportions all the time for summer and autumn, and so do the dwarf shrubs.

On the other hand, the percentage change for the 3 components in relation to each other, and due to increased number of harvests, shows very clear trends that graminids decrease and herbids increase. For the dwarf shrubs there is a decrease only in the ungrazed *Avenetum*, but in grazed *A.* the figures are irregular.

In the ungrazed *A.*, graminids change from 61% to 29% and herbids from 28% to 68% with the increased wear. In fenced and unfenced grazed *A.* there is a decrease of graminids from 51% and 48% respectively to 33% and 34% respectively and for herbids an increase from 48% and 43% respectively to 64% and 61% respectively. The range of the change is thus smaller in grazed than in ungrazed *A.* (Fig. 12).

The values of plots harvested in one year (BI) show that there is a higher proportion of graminids in ungrazed than in grazed *A.* Herbids, in contrast to graminids, have higher values than in ungrazed *A.* Altogether these figures demonstrate that there is a change in the vegetation (adaptation) due to the wear, in this case caused by harvest. Such an adaptation to wear has already taken place in the grazed *A.*, providing a higher tolerance to the intensified wear caused by the harvests.

Returning to the situation in Table 11, it can be seen that the subplots AIV in grazed-fenced and

ungrazed-fenced *A.* show almost identical figures. Table 13 shows that these plots have almost the same composition concerning the percentage of graminids, herbids, and dwarf shrubs. This composition also applies to grazed-unfenced *A.*, but the production figure for the latter is lower, caused by the grazing (Table 11). A similar trend, but with other figures, is obtained for the plots in *F.* The results above confirm that an adaptation has taken place, giving almost the same final composition both for ungrazed and grazed areas, due to the harvests.

The herbids adapt to grazing (or harvest) by developing dwarf or prostrate growth forms. Graminids do not have the same ability and are hereby more easily grazed, resulting in lower proportions of crops from grazed areas.

Another comparison with Table 13 is available in Table 14, which shows separated components in 1970 compared with those in 1972 in plots representing 2 and 4 years of harvests. The same trends are found with decreased proportions of graminids and dwarf shrubs, and increased proportions of herbids, which is more or less pronounced in the six types of sample plots. The lower proportions of graminids in 1970, are most interesting, being most pronounced for grazed-fenced *A.* and *F.* and grazed-unfenced *A.* This cannot have been caused solely by the harvest treatment, as these types of plots are supposed to withstand wear better. A more relevant explanation is possibly a stronger impact on graminids than on herbids by a lasting effect of drought in 1969 in the short grazed vegetation compared with the thick sward in ungrazed areas. Drastic decreases in cover values were obtained for graminids in 1970, but not in figures showing differences between grazed and ungrazed areas.

Further information on effects on vegetation composition caused by cutting and grazing are given by, e.g., Jones (1967) from hill pastures in Wales, and Wells (1971) from chalk grassland in England.

3.2.2 Yearly recordings of phanerogams

There is not space to present the records from all the 60 sample plots in the present context and thus only a few representative ones have been selected. Tables 15—18 illustrate the development in the test plots due to the cuts in 1969—72 and one year after the end of the cutting programme (1973). These values may be compared with those in the control plots during 1969—72.

For grazed alvar areas are 3—4 sample plots representing each type. In ungrazed areas there are 5 plots of the *Avenetum* and 5 of the *Festucetum.* All these plots were chosen from the plots earlier given random priority for harvest and separation in 1972, thus representing all the research areas on the Alvar. The control plots not altered by harvest (1972) are shown in Tables 19 and 20 over a period of 11 years (1969—1979), with 1 *Festucetum* plot and 8 *Avenetum* plots available.

Dynamics in control plots (Avenetum)

Table 20 shows that rather few taxa reach high cover values in the plots. Among graminids, *Festuca ovina* and *Arrhenatherum pratense* seem clearly to be the most important taxa with high cover values. *Filipendula vulgaris* has the highest values among herbids. High values are also obtained for *Artemisia laciniata* and *Achillea millefolium,* but they are not present in the main part of the plots. Regularly present but with lower cover values are *Potentilla* spp., *Plantago lanceolata, Galium verum,* and among dwarf shrubs *Helianthemum nummularium, H. oelandicum,* and *Thymus serpyllum.* Frequently present with low cover values are, e.g., *Agrostis tenuis, Carex ericetorum, Luzula campestris, Cerastium* spp., *Sedum acre, Anthyllis vulneraria, Lotus corniculatus, Oxytropis campestris, Antennaria dioeca* and *Hieraceum pilosella.* Regular occurrence may also be found within single or a few plots as shown, e.g., by *Sesleria coerulea* ssp. *uliginosa, Anemone pratensis, Sedum reflexum,* and *Veronica spicata.* Very irregular occurrence within a plot is shown, e.g., by *Trifolium campestre, T. repens, T. arvense, Myosotis stricta,* and *Taraxacum* spp. Single occurrences recorded, e.g., by *Scleranthus annuus, Erophila verna,* and *Stellaria graminea.*

The total number of recorded taxa (67), is divided over dwarf shrubs (4), graminids (13) and herbids (50). In reality the number of herbids is somewhat higher as some of them have been collectively recorded for technical reasons (see

Chapter 1). Of the total number of taxa a little more than 20% are annuals (15). With some exceptions, the composition of taxa in the plots remains the same.

Examination of the number of taxa per plot gives the result that plots nos. 36, 38 and 39 have a smaller number of taxa than the other plots, on average for the 11 years. Plots nos. 54, 57 and 58 have the lowest number of annuals (Table 21).

Local variations in soil depth and composition of the plant cover may create these differences. In plot no. 54, with the lowest number of annuals, there is very strong competition, mainly between *Artemisia laciniata, Achillea millefolia, Galium verum,* and *Helianthemum nummularium,* giving very few opportunities for annuals to colonize. Also *Filipendula vulgaris* is weak in that plot.

The variation between highest and lowest number of taxa (range) within certain plots is shown in Table 21. Regarding all plots, there is a variation in amplitude from 4—9 for all taxa, (i.e., no. of taxa as given in the tables) and 2—7 for annuals. There is no pronounced difference between the plots in spite of plots nos. 27 and 30 being located in a grazed area. There has been no sheep-grazing in the area since 1971 but then it became fairly heavily grazed by cattle, influencing unfenced plot no. 27.

If a mean value for all taxa recorded in all 8 sample plots in a certain year is created and then these 11 years are compared it is found that the variation in number of taxa between years is rather small. Between highest and lowest number of taxa during the period the difference is 4.6 for all taxa and 2.9 for the annuals. In 1970 the highest mean value is recorded for both annuals and all taxa (Table 22).

In 1975 (the driest year) the lowest mean value for all taxa is found (19.3); during 1977—79 the mean value of annuals were lower than earlier (1.4—1.6). The increase in taxa from 1969 to 1970 may to some extent be explained by difficulties in finding small-sized taxa when the records were made in the very dry vegetation of the first year. However, studies of the plots reveal regularities in the composition of plant cover in each separate year, which would not be seen if too many taxa had been neglected in 1969.

There has been a dynamic situation within the plots during these 11 years which is clearly seen by the cover degrees of the predominant taxa. In all plots *Festuca ovina* decreases considerably from 1969 to 1970, probably due to the summer drought in 1969 that might have killed a large part of the population. A long period of recolonization then follows. A few plots recover within a few years but most of them needed roughly 10 years to reach the cover value of 1969. In some cases this has taken place mostly in competition with *Arrhenatherum pratense.* When the graminids decreased a few herbids with high competitive ability could increase their cover. This applies foremost to *Filipendula vulgaris,* which started to increase its cover in 1970 and then continued to increase in 5 of the plots during the 10-year period. Other plants which increased within a few years were *Arrhenatherum pratense, Achillea millefolia, Helianthemum nummularium, Thymus serpyllum, Galium verum,* and *Potentilla* spp. *Anthyllis vulneraria* should be mentioned as it had a favourable year in 1971 when it grew vigorously in almost all plant communities of the Alvar (Plate 1:2). This feature was also recorded in three of my plots.

Helianthemum nummularium seemed to decrease in cover due to drought in 1975; while the annuals increased in number after dry years (Table 22). In some of the plots (nos. 27, 30 and 38) a decrease for the annuals can be traced (Table 20), possibly a result of hard competition with the dominant species increasing their cover by recolonization, and giving very little space for species with low competition ability. This probably takes place in plots which have been grazed before they were enclosed. Plot no. 30 was sheep-grazed and plot no. 38 cattle-grazed; no. 27 (unfenced) sheep-grazed and later weakly cattle-grazed. A weak grazing before enclosure took place also on most of the other plots.

The effect of the increased density of the sward is unfavourable for some taxa, such as *Galium triandrum, Satureja acinos, Arenaria serpyllifolia, Linum catharticum, Bromus hordeaceus,* and *Anthoxanthum odoratum.* The small *Trifolium* species may also be suppressed by the dense vegetation.

Chalk grasslands in England show similar dynamics to the Alvar. In an enclosure (1936—70) the number of taxa decreased. Tall, perennial taxa be-

Table 15. Records of taxa and their cover degrees in harvested test plots (1969–73) and control plots (1969–72) in ungrazed Avenetum vegetation on the Stora Alvaret. Cover values are according to Hult Sernander-Du Rietz. Taxa with single occurrence are added below. (UF = ungrazed, F = fenced, A = test plot, B = control plot, x cf. 3.1.1.)

| | (UG, F) | | |

Avenetum vegetation on the Stora Alvaret. Cover values according to Braun-Blanquet (1964).
Taxa with single occurrence are added below.(G - grazed, UG ungrazed, F fenced, UF - unfenced, A - test plot, B control plot, x cf. 3.1.1)

Plot no.	3 (G, F)										6 (G, F)										28 (G, F)										7 (G, F)				
Subplot	A					B					A					B					A					B					AA				
Total no. of taxa	24	24	25	21	26	22	19	21	21		21	24	22	23	22	20	19	22	22		21	28	24	24	23	21	27	28	24		19	22	21	21	22
Annuals	5	5	7	4	5	3	4	4	3		2	5	3	3	2	3	6	4	3		3	4	4	4	5	3	4	5	2		2	2	3	4	5
Day	17	10	12	31	20	17	10	12	31		17	10	12	31	20	17	10	12	31		18	8	13	2	21	18	8	13	2		17	14	12	24	23
Month	/7	/7	/7	/7	/7	/7	/7	7	7		/7	/7	7	7	7	/7	7	7	7		/7	7	/8	/7	/7	/7	7	/7	/8		7	/7	/7	/7	7
Year	69	70	71	72	73	69	70	71	72		69	70	71	72	73	69	70	71	72		69	70	71	72	73	69	70	71	72		69	70	71	72	73
Graminids																																		
Anthoxanthum odoratum	1	1	1	1	1	1	1	1	1		1	1	1	1	2	1	1	2	1				×	1	1		×	1	1			1	·	1	1
Phleum phleoides	-															×																			
Agrostis tenuis		·									×		1	1	2	1		1	1		×	1	1	1	1				1	1	1	1	1	1
Arrhenatherum pratense	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1		1	1	1	1	1
Festuca ovina	5	1	1	1	1	5	2	3	3		4	1	1	1	1	4	1	1	2		5	1	1	2	1	4	2	2	3		4	1	1	1	1
Bromus hordeaceus			1						-					×							-	1	-				1	1							
Carex ericetorum	1	1	1	1	1	1	1	1	1		1		1	1	1	1			1		1	1	1	1	1	1	1	1	1		1	1	1	1	1
Luzula campestris					·						1			×		×			×		1	1	1	1	1	1	1	1		·				
(No. of graminids)	4	4	5	4	4	4	4	4	4		8	3	5	7	5	7	3	4	6		5	6	6	6	6	4	6	7	7		3	4	5	6	6
Herbids																																		
Rumex acetosella				×	×				-		·	×	1	1																				
Arenaria serpyllifolia			1	1	1				1	×												1	1	1										
Stellaria graminea	1				×	1			1	1						1			1					-				-	×						
Cerastium spp.	1	1	1		1	1	1	1	1	1	1	1	1	×	1	1	1	1	1		1	1	1	1	1	1	1	1	1		1	1		×	×
Viscaria alpina									-	1	1	1	×																1						
Dianthus deltoides	-			-	×						-		-													-									
Ranunculus bulbosus	1	×	-	×	1	×	×							-		×																			
Anemone pratensis																-																			
Teesdalia nudicaulis		1					1		-							-	1																		
Erophila verna	×	1	1		1		1		-			×			-	-								×											
Sedum acre																					×					×	1	1	1		1	1	1	1	1
S. reflexum	1	1	1	1	1	1	1	1	1	1		×			-	-	1	1	1																
Saxifraga granulata					·				-									1			×	1	×	-			1	1							
Fragaria viridis	1	·		-		1			-															-							1	1			
Potentilla spp.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2		1	1	1	1	1	1	1	1	1		1	1	1	1	1
Filipendula vulgaris	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1			1	1	1	1		1	1	1	1	1
Trifolium campestre	1	·	1		1	1			1							1					1	-	1			-									
T. repens		×	1		-							-	×					1	×			1	1												
Anthyllis vulneraria	1	1	2		1	1	1	4			1	1	2	1	1	2	1	3	1		1	1	1	×	×		1	1			3	1	1	1	-
Lotus corniculatus		×	1	-			-				×	1	1	1	1		1	1	1		1	1	1	1	1	1	1	1	1		-	1	1	1	-
Oxytropis campestris	·		·				-				-		-						-		1	1	1	1	1	1	1	1	1		1	1	1	1	1
Linum catharticum	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1		-	1	1				1				1	1	1	1	-
Myosotis stricta		-	×	×																		1	1	1	1						-				
Prunella vulgaris		-																																	
P. grandiflora	1	1	1	1	1						1	1	1	-	1			1																	
Satureja acinos		1					1	-				-																							
Veronica spicata		1	1	1	1		1	1	1		1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1		1	1	1	1	1
Euphrasia spp.	×			-			-					1	1			x	1	1	1		x	x	1	1	×										
Plantago lanceolata	1	1	2	2	2	1	1	1	1		1	1	1	1	1	1	1	1	1		1	×	1	1	1	1	1	1	1		1	1	1	1	1
Galium triandrum	1		1			1			1	1				1		1					1	1	2	2	1	2	1	1		1	1	1	1	1
G. verum	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	2	2	1	2	1	1		1	1	1	1	1
Campanula rotundifolia		·							×		×		×	×								1									-	×			
Antennaria dioeca	1		-		1	1					1	×	-								1	1		×	1	1	1	1	1						
Achillea millefolium	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1		1	1	1	1	1
Artemisia laciniata	·																																		
A. campestris	·													-							1					1	1	1						
Taraxacum spp.		1	1	1	1		1	1	1		1				×		1		1		-	1	1	×		1	1	1	1		1	1	1	1	1
Hieracium pilosella				-																	1	1	1	1	1	1	1	1	1						
(No. of herbids)	18	19	19	16	21	15	15	14	14		12	20	15	14	15	13	16	17	15		15	21	17	17	16	16	20	20	16		13	15	13	12	13
Dwarf shrubs																																			
Helianthemum nummularium	1						1	1	1	1																					1	1	1	1	1
H. oelandicum	1	×	1		×		1	1	1	1																					1	1	1	1	1
Calluna vulgaris	·													1	1	1			1																
Thymus serpyllum					×		1		1	1	1	1	1	1	1	1		-			1	1	1	1	1	1	1	1	1		1	1	1	1	1
(No. of dwarf shrubs)	2	1	1	1	1	3	2	3	3		1	1	2	2	2	0	0	1	1		1	1	1	1	1	1	1	1	1		3	3	3	3	3

Plot no.	5 (G, UF)										29 (G, UF)										8 (G, UF)									
Subplot	A					B					A					B					AA									
Total no. of taxa	16	23	25	22	21	20	27	27	30		28	27	25	26	25	25	27	30	30		21	23	20	18	22					
Annuals	2	5	4	2	1	3	7	4	5		2	2	3	2	3	3	4	3	3		2	2	2	2	3					
Day	16	10	12	31	20	16	10	12	31		18	8	13	2	21	18	8	13	2		17	14	12	24	23					
Month	/7	7	7	7	7	7	7	7	7		7	7	7	8	7	7	7	7	8		7	/7	/7	/7	7					
Year	69	70	71	72	73	69	70	71	72		69	70	71	72	73	69	70	71	72		69	70	71	72	73					
Graminids																														
Anthoxanthum odoratum	1	1	1	1	1	1	1	1	1		-	-	-	-	-	-	-	-	-		-	-	-	-	-					
Phleum phleoides	-	-	-	-	-	-	-	-	-		1	1	1	1	1	-	1	1	1		-	-	1	1	1					
Agrostis tenuis	1	1	1	2	2	1	1	1	1		1	1	1	1	1	x	1	1	1		1	1	1	1	1					
Arrhenatherum pratense	1	1	1	-	-	1	1	1	1		1	1	1	1	1	1	1	1	1		1	1	1	1	1					
Festuca ovina	4	1	1	1	1	4	1	1	1		4	1	1	1	1	1	1	1	1		1	1	1	1	1					
Bromus hordeaceus	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-		-	-	-	-	-					
Carex ericetorum	1	-	1	1	1	1	-	1	1		1	1	1	1	1	1	1	1	1		1	1	1	1	1					
Luzula campestris	×	-	×	-	-	-	-	-	1		1	×	1	×	1	1	-	1	1		1	1	1	1	1					
(No. of graminids)	6	4	6	4	4	6	4	5	6		7	6	6	6	6	5	5	6	7		4	5	5	5	8					
Herbids																														
Rumex acetosella																														
Arenaria serpyllifolia																														
Stellaria graminea	-	1	1	1	×	-	1	1	1		-	-	-	-	-	-	-	-	-		-	-	-	-	-					
Cerastium spp.	1	1	1	-	-	1	1	1	1		1	1	1	1	1	1	1	1	1		1	1	1	1	1					
Viscaria alpina																														
Dianthus deltoides	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-		-	-	-	-	-					
Ranunculus bulbosus	-	-	-	-	-	-	1	1	-		-	-	-	-	-	-	-	-	-		-	-	-	-	-					
Anemone pratensis	-	-	-	-	-	-	-	-	-		1	1	1	1	-	1	1	1	1		-	-	-	-	-					
Teesdalia nudicaulis	-	-	-	-	-	-	1	-	-		-	-	-	-	-	-	-	-	-		-	-	-	-	-					
Erophila verna	-	-	-	-	-	-	-	-	-		-	-	-	-	×	-	-	-	-		-	-	-	-	-					
Sedum acre	-	-	-	-	-	-	-	-	-		1	1	×	1	1	1	1	1	1		1	1	1	1	1					
S. reflexum	-	-	-	-	-	1	1	1	1		-	-	-	-	-	-	-	-	-		-	-	-	-	-					
Saxifraga granulata	-	-	-	-	-	-	-	-	-		1	1																		
Fragaria viridis	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-		-	-	-	-	-					
Potentilla spp.	-	1	1	1	1	-	1	1	2		1	1	1	1	1	1	1	1	1		1	1	1	1	1					
Filipendula vulgaris	-	x	1	1	1	-	1	1	1		1	1	1	1	1	1	1	1	1		1	1	1	1	1					
Trifolium campestre	-	-	-	-	-	-	1	-	-		-	-	-	-	-	-	-	-	-		-	-	-	-	-					
T. repens	-	-	1	1	×	-	×	1	1		-	-	-	-	-	-	-	-	-		-	-	-	-	-					
Anthyllis vulneraria	3	1	1	1	1	3	1	2	1		1	1	1	1	1	-	-	1	-		-	1	-	-	-					
Lotus corniculatus	-	1	1	1	1	-	1	1	1		1	1	1	1	1	1	1	1	1		1	1	1	1	1					
Oxytropis campestris	-	-	-	-	-	-	-	-	-		1	1	1	1	1	1	1	1	1		1	1	1	1	1					
Linum catharticum	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1		1	1	1	1	1					
Myosotis stricta	-	1	1	×	-	-	×	-	×		-	-	-	-	-	-	-	-	-		1	×	1	1	-					
Prunella vulgaris	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-		-	-	-	-	-					
P. grandiflora	1	1	1	1	1	1	1	-	x		-	-	-	-	-	-	-	-	-		-	-	-	-	-					
Satureja acinos	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-		-	-	-	-	-					
Veronica spicata	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1		1	1	1	1	1					
Euphrasia spp.	-	1	×	-	-	×	1	1	1		-	-	-	-	-	-	-	-	-		-	-	-	-	-					
Plantago lanceolata	1	-	1	1	-	-	-	1	1		1	-	1	1	1	1	-	1	1		1	-	1	1	1					
Galium triandrum	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1		1	1	1	1	1					
G. verum	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1		1	1	1	1	1					
Campanula rotundifolia	-	×	-	×	-	-	-	-	-		-	-	-	-	-	-	-	-	-		1	1	1	1	1					
Antennaria dioeca	-	-	-	-	-	-	-	-	-		1	1	-	x	1	1	1	1	1		1	1	1	1	1					
Achillea millefolium	1	1	1	1	1	1	1	1	1		1	1	1	2	1	1	1	1	1		1	1	1	1	1					
Artemisia laciniata	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-		-	-	-	-	-					
A. campestris	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-		-	-	-	-	-					
Taraxacum spp.	-	1	1	1	1	-	1	1	1		-	1	1	×	x	-	1	1	1		1	1	1	1	1					
Hieracium pilosella	-	-	-	-	-	-	×	-	-		1	1	1	1	1	-	1	1	1		1	1	1	1	1					
(No. of herbids)	9	19	17	16	13	12	21	19	21		18	18	16	17	16	17	19	21	20		14	15	13	11	11					
Dwarf shrubs																														
Helianthemum nummularium	-	-	-	×	×	×	1	1	1		1	1	1	1	1	1	1	1	1		1	1	1	1	1					
H. oelandicum	x	-	1	×	×	1	1	1	1		1	1	1	1	×	1	1	1	1		1	1	1	1	1					
Calluna vulgaris	-	-	-	-	×	-	-	-	-		-	-	-	-	-	-	-	-	-		-	-	-	-	-					
Thymus serpyllum	-	-	1	-	1	-	-	1	1		1	1	1	1	×	1	1	1	1		1	1	1	1	1					
(No. of dwarf shrubs)	1	0	2	2	4	2	2	3	3		3	3	3	3	3	3	3	3	3		3	3	3	3	3					

Phleum bertolonii plot 8AA: 1972(1), 1973(1); Arrhenatherum pubescens plot 29 B: 1972(1); Briza media plot 6A: 1969(1), plot 5B: 1969(x), plot 29A: 1969(1); Poa compressa plot 6A: 1969(1); Orchis mascula plot 6A: 1973(x), plot 6B: 1971(1); Polygonum aviculare plot 5A: 1970(x); Scleranthus annuus plot 28B: 1971(1), plot 29B: 1970(x); Sagina nodosa plot 5A: 1970(x); Gypsophila fastigiata plot 8AA 1969(1), Arabis hirsuta plot 7AA: 1972(x); Saxifraga tridactylites 28B: 1969(1), plot 29B: 1969(1); Medicago lupulina plot 6B 1971(1), Trifolium arvense plot 3A: 1970(x), plot 6A: 1970(x). plot 6B: 1970(1); Hypericum perforatum plot 3A: 1972(x), 1973(x); Viola sp. plot 5B: 1972(x); Veronica praecox plot 3A: 1972(x), plot 7AA: 1973(x), plot 5B: 1972(x); Crepis tectorum ssp.

Table 17. Records of taxa and their cover degrees in harvested test plots (1969-73) and in control plots (1969-72) in ungrazed Festucetum vegetation on the Stora Alvaret. Cover values are according to the 5 degree scale by Hult-Sernander-Du Rietz. Taxa with single occurrence are added below. UG = ungrazed, F = fenced, A = test plot, B = control plot, x cf. 3.1.1)

Plot no.	9									22										41										46										50									
Subplot	A					B				A					B					A					B					A					B					A					B				
Total No. of taxa	6	8	6	3	4	4	6	7	7	6	12	12	11	10	7	14	10	9		6	12	6	10	10	8	16	12	11		6	13	16	11	8	5	12	13	14		7	12	12	12	11	6	14	13	12
Annuals	0	1	1	1	1	0	1	1	1	1	3	3	2	3	1	3	2	2		0	2	2	2	2	0	2	2	2		1	2	4	1	2	1	3	2	2		1	5	5	5	4	0	6	4	2
Day	17	6	8	24	17	17	6	8	24	18	6	8	27	17	18	6	8	27		20	22	9	6	19	20	22	9	6		19	19	12	2	17	19	19	12	2		21	12	7	23	23	21	12	7	23
Month	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7		7	7	7	8	7	7	7	7	8		7	7	7	8	7	7	7	7	8		7	7	7	7	7	7	7	7	7
Year	69	70	71	72	73	69	70	71	72	69	70	71	72	73	69	70	71	72		69	70	71	72	73	69	70	71	72		69	70	71	72	73	69	70	71	72		69	70	71	72	73	69	70	71	72
Graminids																																																
Phleum bertolonii	1	1	x							1	1	1	1	x	1	1	1	1			x					x	1			x	x	x	1	1	x			1		1	1					1	1	1	1
Agrostis stolonifera	2	1	1	1	1	2	3	2	1	2	1	1	1	1	2	1	2	1		2	1	1	1	1	1	1	1	1		2	1	1	1	1	2	2	2	2		1		1	x	x			1	1
Poa compressa	-	-	-	-	-	-	-	-	-	-										1	1	1	1	1						1	1	1	1	1		1	1	1										
Festuca rubra ssp. oel.	1	1				1	1	1	1	1	x	1	x	x	1	x	1	1		1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1		2	1	1	1	1	1	1	1	1
F. ovina	3	1	1	1	1	3	3	3	3	3	1	1	1	1	3	2	3	3		3	1	1	1	x	3	1	2	2		4	1	1	1	1	4	1	2	2		2	1	1	1	1	2	2	3	3
(No. of graminids)	4	4	3	2	2	3	3	3	3	4	4	4	4	4	4	4	4	4		3	4	3	3	3	4	6	5	4		5	5	5	5	5	4	4	4	5		4	3	3	3	3	3	3	4	4
Herbids																																															
Herniaria glabra																														1	1			1	1	x												
Sagina nodosa	-	-	-		-	-	-	-	-	-	x	1	1	x		1	1	1													x				1	1											
Cerastium spp.	-	-			-	-	-	-	-	-	1	1	-	x		1														1	1				1										x			
Silene maritima var.petr.	-	-	-	-	-					-	-	-																																	1	1	1	1	1
Erophila verna																														1	1		1		1												1		
Sedum album																							1			x					1	x	x		1	1	x		1		-							
Medicago lupulina																																					x		1	x									
Linum catharticum	-	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1			1	1	1	1		1	1	1		x	1	1	1	1	x	1	1	1		1	1	1	1			1	1	1
Anagallis arvensis																							x																	x	1	1	x	1		x	1	
Myosotis stricta																																										1	1	1		x			
Satureja acinos	-	-		-	-			-	-	-	1	1	1			x					1		x			x				1	1	1			1	1	x		1	1	1	1			1	1	1
Chaenorrhinum minus																																								1	1	1	1			1	1	1
Euphrasia spp.	-	-	-	-	-				-	-	1	1	1	1		1	1	1		1	1	1				1	x	1			1																	
Galium pumilum	-	-	-	-	-	-	-	-	-		x	1	x	-	1	1	1	1																												1	1	1	1
Cirsium vulgare	-	x	1																											1	1	1								x	x	1						1
C. acaule																										x	1	1																			
C. arvense	-	-	-		1	-		1	1																																							
Leontodon autumnalis	-	x		-		-	x	x	1								x			1	1	1	1	x	1	1	1	1			x	1			1	1	1					x				x		
Taraxacum spp.	x																x									x						x																
Hieracium spp.	1	1	1			1	1	1	1		x	x	x	x		x	x				1		x	1	1	1	1			x							1	1										
(No. of herbids)	2	4	3	1	2	1	3	4	4	1	7	7	6	5	2	9	5	4		1	6	3	5	5	2	8	5	5		1	7	10	6	3	1	7	8	8		8	8	8	7		10	6	7
Dwarf shrubs																																															
Helianthemum oelandicum																																															
Thymus serpyllum	-	-						-	-	1	1	1	1	x	1	1	1	1		1	1		1	1	1	1	1	1			x	1			x	1	1			1	1	1	1	1	1	1	1	1
(No. of dwarf shrubs)	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1		2	2	0	2	2	2	2	2	2		0	1	1	0	0	0	1	1	1		1	1	1	1	1	1	1	1	1

Hornungia petraea plot 50B 1971(x); Anthyllis vulneraria plot 50A 1970(1), 1971(1); Galeopsis ladanum plot 50A: 1970(1), 1972(x); Campanula rotundifolia plot 41A 1970(1); Hieracium pilosella plot 50B: 1971(x), 1972(1). Cover value within brackets.

came dominant, such as *Festuca ovina, Arrhenatherum pratense, Koeleria gracilis,* and *Phleum phleoides.* Temporary increases in abundance due to reduced competition were found for *Thymus drucei* (Watt 1974 pp. 1164 ff.). This could be compared with an increase of *Thymus serpyllum* in my plots after extremely dry years. Several other parallels can be found.

Records from harvested plots (Avenetum)

Examination of Table 15 (*Avenetum* ungrazed-harvested 1969—73) shows a very similar picture to that presented in the 11-year records from the control plots (Table 20). The total number of taxa is lower than in Table 20 as the recording periods is shorter and reflects only 5 plots. Furthermore, they are not located in the same areas as the plots in Table 20. In summary, there are 57 taxa; namely 10 graminids, 43 herbids, and 4 dwarf shrubs. There are 12 annuals, which is 21% of the total number of taxa.

There are very small differences in number of taxa between plots and between years, as already noticed in Table 20. A comparison of control plots (B) and test plots (A) shows no difference in the number of taxa. Annuals may increase slightly in the harvested plots but this is not pronounced. In one sample plot (no. 35) there is a more remarkable difference in number of taxa between the years. Much lower figures are obtained in 1969 and in 1971 in the test plot and in 1969 in the control plot than in the other years. These variations are partly due to annuals but also herbids are involved.

Graminids and dwarf shrubs continued to be present, as found in Table 20. The reason for the disappearance of some taxa in the test plot after 2 or 3 years may be their low resistance to the harvesting treatment. Another explanation may be that they happened to grow outside the recorded plot when the size of the subplot was diminished (cf. discussion in 3.1). The disappearance of, e.g., the following taxa may have been caused merely by the reduction of plot size: *Anemone pratense* and *Sedum reflexum* (plot 15 A), *Antennaria dioeca,* and *Helianthemum oelandicum* (plot 59 A).

Dominant species in the plots are *Festuca ovina* and *Arrhenatherum pratense* among the graminids. *Carex ericetorum* is frequently present. There

Table 18. Records of taxa and their cover degrees in harvested test plots (1969-73) and in control plots (1969-72) in grazed Festucetum vegetation on the Stora Alvaret. Cover values are according to the 5 degree scale by Hult-Sernander-Du Rietz. Taxa with single occurrence are added below. G = grazed, F = fenced, UF = unfenced, A = test plot, B = control plot).

Plot no.	26 (G, F)										31 (G, F)										33 (G, F)										1 (G, F)					
Subplot	A					B					A					B					A					B					A					
Total no. of taxa	7	15	12	9	11	10	16	14	12		6	12	8	10	8	9	12	11	11		9	14	10	8	10	8	12	9	13		10	16	11	10	12	
Annuals	1	4	3	3	4	1	5	3	2		1	4	3	3	4	1	3	3	3		1	4	3	2	2	1	3	1	2		2	4	2	3	6	
Day	19	8	9	23	21	19	8	9	23		19	9	10	27	18	19	9	10	27		19	9	10	27	18	19	9	10	27		21	10	12	25	20	
Month	/7	/7	/7	/7	/7	/7	/7	/7	/7		/7	/7	/7	/7	/7	/7	/7	/7	/7		/7	/7	/7	/7	/7	/7	/7	/7	/7		/7	/7	/7	/7	/7	
Year	69	70	71	72	73	69	70	71	72		69	70	71	72	73	69	70	71	72		69	70	71	72	73	69	70	71	72		69	70	71	72	73	
Graminids																																				
Phleum bertolonii	1	1	x	.		1	x	1	1		1	–	–	x		1	1	1	1			–	x		–	1	1	1	1		–	–	–	–		
Agrostis stolonifera	2	1	1	1	1	2	1	2	2		3	1	1	1	1	3	1	3	2		1	1	1	1	1	1	1	2	2		1	1	1	1	1	
Festuca rubra ssp. oel.		–	–	–	–	–	.	.			–	–	–	–		.	.		–		1	1	1	1	1	1	1	1	1		–	–	–	–	–	
F. ovina	3	1	1	1	1	4	2	3	3		3	1	1	1	1	3	2	3	3		3	1	1	1	1	3	2	3	3		3	1	1	1	1	
Bromus hordeaceus		–	–			–					–	–	–	–		–						–	–	–		–	–	–							
(No. of graminids)	3	3	3	2	2	3	3	3	3		3	3	2	3	2	3	3	3	3		4	5	4	3	3	4	4	4	4		2	2	2	2	2	
Herbids																																				
Sagina nodosa	–	x	x	–	–	–	x	x			–	x		–			1				–	x		–	1		1	1	1			1	1		1	
Cerastium spp.	–	–	–				x		–			1	–		1	–	x				x	1	1	–			1	–	–			1	–		–	
Erophila verna	–	x				–	x		–		–		–								–			–	–		x	–	–		x	1		x	1	
Sisymbrium supinum	–	–	–		–	–		–			–		–			–	–		–		–	1		1	x				–				.	–	
Sedum album	–	x	–		x	x	1	1	x		–	–		–	–			–	.		x	1	–			–	–	–		1	1	1		1	
Linum catharticum	x	1	1	1	1	x	1	1	1		x	1	1	1	1	x	1	1	1			1	1	1	1	x	x	1	1		x	1	1	1	1	
Anagallis arvensis	–	1	x	x	1		1	–	–			1	1	1	1	–	x	1	1		–	–		–	–	–	–	–	–		–	–		–	–	
Convolvulus arvensis	1	1	1	1	1	1	1	1	1		–	–		–	–	–	–		–		–	–		–	–					–			.	–	
Satureja acinos	–		–	–			1	1	1		–			–			–		–		–	–		–			x	–	1		1	1	x	1	
Linaria vulgaris	–	1	1	1	1	1	1	1	1		–	–	–	x	–	–					–	–			–	–	–	–			–	–	–			
Chaenorrhinum minus	–	1	1	1	1	–		x	–		–		–	–	–			–	–																	
Euphrasia spp.	–	–	–		1	–	x	1	1			x	x	x	1			1	1			1	1	–				–	1		–	1	1	1	x	
Galium pumilum		x	x				x		1		x	1	1	x		x	1	1	1		–	–		–	–	–	–	1		1	1	1	1		
Antennaria dioeca	–		–				–		–		–	–	–	–		x	x	x			–	–	–	–	–	–	–	x				–	–		
Leontodon autumnalis	1	1	1	1	1	1	1	1	1			1		–	–				–	1	1	1	1	1	1	1	1	1	1		1	1	–	x	x	
Taraxacum sp.	–		–	–	–		–	–	–				–					–	–	–		–	–	–						–	1	1	1	–	
Hieracium spp.	1	1	1	1	1	1	1	1	1			1	1			1	1	1	1		1	1	1	1	1	1	1	1	1		1	1	1	1	–	
(No. of herbids)	4	11	9	7	9	6	13	10	9		1	7	5	6	5	4	7	6	6		4	8	5	4	6	3	7	4	8		7	13	8	8	10	
Dwarf shrubs																																				
Helianthemum oelandicum	–	–	–	–	–	–	–	–	–		1	1	–	–	–	1	1	1	1		–	–	–	–	–	–	–	–	–		–	–	–	–	–	
Thymus serpyllum	–	x	–	–	–	x	–	1	–		1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1		1	1	–	–		
(No. of dwarf shrubs)	0	1	0	0	0	1	0	1	0		2	2	1	1	1	2	2	2	2		1	1	1	1	1	1	1	1	1		1	1	1	0	0	

Plot no.	25 (G, UF)										32 (G, UF)										34 (G, UF)										2 (G, UF)					
Subplot	A					B					A					B					A					B					A					
Total no. of taxa	9	12	9	9	10	9	13	10	11		7	11	6	4	5	5	12	10	10		6	9	6	6	7	5	7	8	7		5	5	5	4	7	
Annuals	1	4	3	3	3	1	4	1	1		0	3	1	2	2	1	3	2	2		2	2	2	1	2	1	2	2	2		1	0	0	1	4	
Day	19	8	9	23	21	19	8	9	23		19	9	10	27	18	19	9	10	27		19	9	10	27	18	19	9	10	27		21	10	12	25	20	
Month	/7	/7	/7	/7	/7	/7	/7	/7	/7		/7	/7	/7	/7	/7	/7	/7	/7	/7		/7	/7	/7	/7	/7	/7	/7	/7	/7		/7	/7	/7	/7	/7	
Year	69	70	71	72	73	69	70	71	72		69	70	71	72	73	69	70	71	72		69	70	71	72	73	69	70	71	72		69	70	71	72	73	
Graminids																																				
Phleum bertolonii	1	1	1	–	1	1	x	1	1		–	–	–	–	–		–					–	–	–	–	–	–	–	–		–	–	–	–	–	
Agrostis stolonifera	2	1	1	1	1	2	1	2	2		2	1	1	1	1	1	1	2	1		1	1	1	1	1	1	1	2	1		1	1	1	1	1	
Festuca rubra ssp.oel.	1	–	1	–	–	1	–	1	–		–	–	–	–	–	–	–	1	1		–	–	–	–	–	–	–	–	–		–	–	–	–	–	
F. ovina	3	1	1	x	1	3	2	3	3		3	1	1	1	1	3	2	3	3		4	1	1	1	1	3	1	2	2		3	1	1	x	1	
Bromus hordeaceus	–	–	–	–	–	–	–	–	–		–	–	–	–	–	–	x	–	–		–	–	–	–	–	–	–	–	–		–	–	–	–	–	
(No. of graminids)	4	3	4	2	3	4	3	4	3		2	3	2	2	2	2	4	3	3		2	3	2	2	2	2	2	2	2		2	2	2	2	2	
Herbids																																				
Sagina nodosa	–	x	–	–	x	–	x	–	–		–	x	1	–	x	–	1	1	1		–	–	–	–	x	–	–	1	1		–	1	1	–	1	
Cerastium spp.	–	–	–	–	–	–	x	–	–		–	–	–	–	–	–	x	–	–		–	–	–	–	–	–	–	–	–		–	–	–	–	1	
Erophila verna	–	–	–	–	–	–	–	–			–	–	–	–	–	–		–	–		–	–	–			–	x	–	–		–	–	–	–	–	
Sisymbrium supinum	–	–	–	–	–	–	–	–								–	–	–	–		–	–	–	–	–	–	–	–	–		–	–	–	–	–	
Sedum album	–	–	–	–	–	–		–			–	x	–	–	–		x	–	–		–	–	–	–	–	–	–	–	–		–	x	–	–	–	
Linum catharticum	x	1	1	1	1	x	1	1	1			1	1	1	1	x	x	1	1		x	1	1	x	1	x	1	1	1		x			1	x	
Anagallis arvensis	–	1	1	1	1	–	x	–	–			1		x	1	–	–	–	–		–	–	–	–	–	–	–	–	–		–	–	–	–	–	
Convolvulus arvensis	–	–	–	–	–						–	–	–	–	–						–	–	–	–	–	–	–	–	–							
Satureja acinos	–	x	1	x	1	–	1	1	1						–	–	–	–	–		–	1	–	x	–		1	1	–		–	–	–	–	–	
Linaria vulgaris	x	–	–	–	–	–	–	–	–							–	x	1	x																	
Chaenorrhinum minus	–	1	1	1	1	–	x		–		–	–	–		–		–	–	–							–	–	–	–				–	–	–	
Euphrasia spp.	–	1	–	–	–		x	1			–	–	x	1		–	–	x	1		1	1	x	–	1		–	x	1		–	–	–	–	x	
Galium pumilum	–	x	–	–	–	1	1	1	1		x	1	–			–	–	–	–		–	–	–	–	–	–	–	–	–		–	–	–	–	–	
Antennaria dioeca	–	–	–	–	–		–	–	–		–	–	–	–			–	–	–			–	–	–	–	–	–	–	–							
Leontodon autumnalis	1	1	1	1	1	1	1	1	1		1	1	1		–	1	1	1	1			–	–	–	–	–	–	–	–		1	x	1	x	–	
Taraxacum sp.	–	–	–	–	–		–	–	–							–	–	–	–			–	–	–	–	–	–	–	–		–	–	–	–	–	
Hieracium spp.	x	1	–	1		1	1	1	1		x	–	x		–		x	1	1		–	1	x	–	–	–	–	–	–		–	–	–	–	–	
(No. of herbids)	4	9	5	6	6	4	9	5	7		3	7	4	2	3	2	7	6	6		2	4	3	2	3	1	3	4	3		3	3	3	2	5	
Dwarf shrubs																																				
Helianthemum oelandicum	–	–	–	–	–	–	–	–	–		1	–	–	–	–	–	–	–	–		1	1	–	1	1	1	1	1	1		–	–	–	–	–	
Thymus serpyllum	x	–	–	1	1	1	1	1	1		1	1	–	–	–	1	1	1	1		1	1	1	1	x	1	1	1	1		–	–	–	–	–	
(No. of dwarf shrubs)	1	0	0	1	1	1	1	1	1		2	1	0	0	0	1	1	1	1		2	2	1	2	2	2	2	2	2		0	0	0	0	0	

Poa compressa plot 33A: 1969(1), 1970(1); Herniaria glabra plot 1A:1970(x); Arenaria serpyllifolia plot 1A: 1973(x); Hornungia petraea plot 1A:1973(x); Saxifraga tridactylites plot 1A:1973(1), plot 2A: 1973(1); Fragaria viridis plot 33A: 1973(x); Anthyllis vulneraria plot 2A: 1970(x); Prunella vulgaris plot 1A: 1969(x), plot 2A: 1969(1); Cirsium vulgare plot 25B: 1972(x); Crepis tectorum ssp. pumilum plot 1A: 1970(x).- Cover value within brackets.

Table 19. Recorded taxa in ungrazed fenced Festucetum in 1969-1979. Cover values according to the 5 degree scale (Hult Sernander-Du Rietz). - Alvar of Gettlinge.

Plot no.	42										
Total no. of taxa	6	9	9	10	8	9	7	12	9	9	11
Annuals	0	1	1	2	1	2	1	2	2	1	3
Day	20	22	9	6	19	8	22	13	17	23	17
Month	/7	/7	/7	/8	/7	/8	/8	/8	/9	/8	/8
Year	69	70	71	72	73	74	75	76	77	78	79
Graminids											
Agrostis stolonifera	1	1	1	1	1	1	1	1	1	1	2
Festuca rubra ssp. oel.	1	1	1	1	2	1	2	2	2	2	2
F. ovina	3	1	1	1	1	1	1	2	2	2	3
Herbids											
Sagina nodosa	-	-	-		-	-	-	1			
Cerastium sp.	-	-	-	-	-	-	-	-	-	-	×
Arabis hirsuta	-	-	-	-	-	-	-	-	-	1	-
Sedum album	-	×	-	-	-	-	-	-	-		
Potentilla sp. (juv.)	-	-	-	-	-	-	-	-	-	-	×
Linum catharticum	-	1	1	1	×	1	1	1	1	1	1
Satureja acinos	-	-	-	-	-	-	-	×	-	×	-
Euphrasia spp.	-	-	-	1	-	×	-	1	1	-	×
Leontodon autumnalis	×	1	1	1	-	-	-	×	1	×	1
Taraxacum sp.	-	×									
Hieracium sp.	1	1	1	1	1	×	-	1	×	-	1
Dwarf shrubs											
Helianthemum nummularium	-	-	1	1	1	1	1	1	-	-	-
H. oelandicum	-	-	1	1	1	1	1	1	1	1	1
Thymus serpyllum	1	2	2	2	2	2	1	1	1	1	1

is a decrease in cover values for *Festuca ovina* from 1969 to 1970, which is clearest in the harvested plots. Among herbids, *Filipendula vulgaris* has the highest cover values. Taxa such as *Potentilla* spp., *Veronica spicata, Plantago lanceolata* and *Galium verum* are frequently present, sometimes with increased cover. *Filipendula, Plantago,* and *Galium* seem to withstand the cuts fairly well as they increase to some extent (Plate 2:1—4). *Thymus serpyllum* also increases but not in harvested plots. *Orchis mascula* resists the harvesting treatment fairly well as its tuber formation in early summer is not directly disturbed by the cut. *Luzula campestris* may suffer but *Arenaria serpyllifolia* may be favoured. The figures do not permit any further conclusions to the drawn.

Records in grazed-fenced and grazed-unfenced *Avenetum* are found in Table 16. No large differences are found by comparing fenced and unfenced plots due to number of taxa. Totally there are 58 taxa in fenced and 56 in unfenced with respectively 14 and 13 annuals. In fenced and unfenced together there is a total of 67 taxa.

The number of taxa remains fairly constant in the plots. An increased number of herbids is found in plot 6 A from 1969 to 1970 with a contemporary decrease of graminids from 8 to 3 taxa. In plots 5 A and 5 B, herbids also increase considerably but there is only a small decrease for graminids. These increases include both annuals and other taxa.

Festuca ovina decreases from 1969 to 1970, the decrease again being more pronounced in the harvested plots. In these grazed plots *Filipendula vulgaris* does not seem to be as dominant as in ungrazed areas. Instead, many taxa are rather frequent, such as *Potentilla* spp., *Veronica spicata, Plantago lanceolata, Galium verum, Achillea millefolia,* and *Anthyllis vulneraria.*

Some of these taxa were considered by Ljung 1970 (cf. 7.1.2) to have a high tolerance to grazing. *Plantago* is able to increase its cover in the plots more permanently but *Galium* and *Anthyllis* on the other hand, are only able to increase more occasionally. Among the graminids *Agrostis tenuis* seems to be rather resistant to harvest. A few other taxa which also seem to be more frequent in grazed than in ungrazed areas are, e.g., *Stellaria graminea, Taraxacum* spp., *Rumex acetosella, Cerastium* spp. and *Myosotis stricta.* Some of these seem to be favoured by a decreased competition, e.g., *Rumex acetosella,* which only occurs in cut plots. The *Helianthemum* species are less frequent in grazed areas than in ungrazed.

Between cut and uncut plots there are generally no pronounced differences (Table 16). No explanation of the very high values for standing crop in grazed-fenced plots in 1972 is provided by these records. A general increase of growth in the plots after enclosure must be the answer.

Orchis mascula was recorded in fenced plot no. 6 twice during the investigation. Orchids in general are very rare in sheep-grazed areas on the Alvar. *Viscaria alpina* is also found in plot no. 6.

Impact by harvest will not change the dominance in grazed plot as much as it does in an ungrazed one. In the latter, removal of tall taxa as, e.g., *Arrhenatherum pratense* and *Filipendula vulgaris,* will totally change the competitive conditions and the composition of the vegetation. In grazed plots the dominance is shared by several taxa, which must be the reason for the more stabilized situation in grazed areas (also discussed earlier in this chapter in connection with changes in production values.

Dynamics in the control plot (Festucetum)

A look at the records from one single sample plot of the *Festucetum* during 1969—1979 (Table 19) shows that the number of graminids has remained

constant (3) during the period. Dwarf shrubs show a small variation and herbids the largest variation. Within the herbids this variation depends very little on the annuals as they are only 3 of 11 recorded taxa. Altogether 17 taxa were found during the period.

As in the *Avenetum, Festuca ovina* decreased due to the drought in 1969 and then slowly recovered, not reaching the cover degree of 1969 until 1979. Another grass, *Festuca rubra* ssp. *oelandica,* also increased during these 11 years. *Thymus serpyllum* reached a high cover value after 1969 (cf. Table 20) but then decreased as the *Festuca* increased. Among herbids, *Leontodon autumnalis, Hieracium* sp., and *Linum catharticum* were frequently present during the period, as was *Agrostis stolonifera.* Variations in number of taxa are found, increasing after a dry period.

Records from harvested plots (Festucetum)

Table 17 represents the ungrazed *Festucetum.* Plot no. 9 differs from the others as it has a smaller number of taxa and is completely without dwarf shrubs. It has also the smallest proportion of annuals, which are more frequent in the other plots, especially in no. 50. Graminids and dwarf shrubs show small variations in occurrence during the period but the herbids are responsible for the obvious variations. Among the 32 taxa recorded there are 10 annuals, thus more than in Table 19 and in the *Avenetum* plots.

In 1970 there was also a decrease for *Festuca ovina,* being most pronounced in harvested plots. A considerable increase of taxa took place in 1970. About half that increase is related to annuals and the rest to other herbids. Permanently present taxa are, e.g., *Agrostis stolonifera* (including *A. gigantea*), *Festuca ovina, F. rubra* ssp. *oelandica,* and *Linum catharticum*; those frequently occurring were *Phleum bertolonii, Leontodon autumnalis, Hieracium* spp., and *Thymus serpyllum* (cf. Plate 2:5—8).

Grazed *Festucetum* is shown in Table 18. For the fenced plots there were 30 taxa with 5 graminids, 23 herbids and 2 dwarf shrubs (10 annuals). In the unfenced plots there were 24 taxa with 5 graminids, 17 herbids and 2 dwarf shrubs (8 annuals). There is a larger number of herbids in fenced plots and also a slightly larger number of annuals. Annual mean values for fenced and unfenced plots show the same trend as above, with a larger number of taxa and annuals in 1970 (Table 23).

The annuals were probably favoured in 1970 due to the decrease of *Festuca ovina.* Permanently present with high cover values are *Agrostis stolonifera* (incl. *A. gigantea*), and *Festuca ovina*; with low cover *Linum catharticum, Leontodon autumnalis, Hieracium* spp., and *Thymus serpyllum,* all both in fenced and unfenced plots.

Irregularly occurring annuals are, e.g., *Sagina nodosa, Cerastium* spp., *Erophila verna,* and *Sisymbrium supinum.* As might be expected, graminids were suppressed by cutting and the following increased frost-induced soil movements in this plant community.

3.2.3 Yearly recordings of mosses and lichens

To complete the information about vegetation in cut and uncut sample plots, mosses and lichens were recorded during the years 1971—74. In 1971—72 all plots were recorded but in 1973 only the harvested subplots II and IV. A part of these cut plots was then recorded in 1974. The investigations were carried out in September or October. Cover degrees according to Hult-Sernander-Du Rietz were used (see 3.1.1). The full material of recordings is kept at the Institute of Ecological Botany. Some features have been extracted and given below.

The records show fairly small differences in number of taxa between grazed and ungrazed plots, applying to both the *Avenetum* and the *Festucetum.* In all types of sample plots there is a variation in number of taxa from one plot to another. This variation is to some extent due to the location of the plot, i.e., an extremely dry site, a temporarily wet site, type of soil, competition of vascular plants, etc.

Grazed fenced and unfenced plots are treated together as they show no clear differentiation. However, it must be mentioned that the sizes of lichens in grazed sample plots is often smaller than in ungrazed ones. In addition, the big lichens often cover larger parts in ungrazed than in grazed plots. These differences are obviously caused by the trampling which often fragments the lichens in

Table 20. Records of taxa and their cover degrees from unharvested permanent sample plots (control) in Avenetum vegetation on the Stora Alvaret in 1969-79. Cover values are according to the 5 degree scale by Hult-Sernander-Du Rietz. Taxa with single occurrence are added below. (G = grazed, UG = ungrazed, F = fenced, UF = unfenced x cf. 3.1.1)

Plot no.	27 (G, UF)												30 (G, F)												36 (UG, F)												38 (UG, F)											
Total no. of taxa	25	27	25	26	25	26	24	29	23	22	20		25	25	26	28	27	27	22	26	22	21	20		16	21	21	16	20	19	16	19	16		19	22	21	23	21	20	15	17	14	1	
Annuals	3	5	2	4	3	3	3	5	1	1	0		3	5	5	4	5	5	3	5	1	1	1		2	4	6	2	6	4	4	5	3	5	2		5	5	6	7	8	5	4	4	1		
Day	18	8	13	2	21	13	23	17	18	23	19		18	8	13	2	21	13	23	17	18	23	19		20	16	9	12	19	8	22	13	17	23	17		20	16	9	12	19	8	22	13	17	2	
Month	/7	/7	/7	/8	/7	/8	/8	/8	/9	/8	/8		/7	/7	/7	/8	/7	/8	/8	/8	/9	/8	/8		/7	/7	/7	/8	/7	/8	/8	/8	/9	/8	/8		/7	/7	/7	/8	/7	/8	/8	/8	/9		
Year	69	70	71	72	73	74	75	76	77	78	79		69	70	71	72	73	74	75	76	77	78	79		69	70	71	72	73	74	75	76	77	78	79		69	70	71	72	73	74	75	76	77	78	79
Graminids																																														
Anthoxanthum odoratum	-	x	x	-	-	-		x	-	-			-	-					-						-						-	-	-												
Phleum bertolonii	-	-				-	-			-	-				-	-	-			-								-	-	-														
P. phleoides	1						x		1	1	1		1	1	1	1	1	1	1	1	1	1	1						-																
Agrostis tenuis	1		1	1	1	1	1	1	1	1	1		x		1	1	-	1	1	1	1	1							-																x
Arrhenatherum pratense	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	2	2	2	2	2	2	2		1	1	1	1	1	1	1	1	1	1	
A. pubescens	-				-														-							-			-															
Sieglingia decumbens	-	-	-	-	-	-	-												-						-	-			-															
Sesleria coerulea ssp. uliginosa	-	-	-	-	-	-	-						-								-	-	-									-	-											
Briza media	-	-					-				-	-										-	-																					
Festuca ovina	4	1	1	1	2	2	2	3	3	3	4		4	1	1	1	2	2	2	2	2	3	4		4	2	3	3	3	2	3	2	3	4	4		4	1	3	3	3	3	4	4	4	4	
Bromus hordeaceus	-	x		-			x	1	-										1							1	1	x	x	1	1	1	x			1	2	1	1	1	1	1	1			
Carex ericetorum	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1										-												
Luzula campestris	1	1	1	1	1	1	1	1	1	1	1		1	-		1	1	1	1	1	1	1	1																							
Herbids																																													
Allium vineale	-	-	-	-	-	-								-		-			-										-	-														
Arenaria serpyllifolia	-	-	1	1	1	1	1	1	-						1	1	1	1	1	1							1		1	x	1	1		1	1				1	1	1	x	1				
Cerastium spp.	1	1	1	1	1	1	1	1	1	1	-		1	1	1	1	1	1	1	1	1	x	x			1	1	-	1	1	1	1	1	1	1		x	1	1	1	1	1	1	1	1	1	
Ranunculus bulbosus	-	-	-	-									-								-	-	-						-	-															
Anemone pratensis	-	-	-	-	-	-	-		-	-				1	1	1	1	1	1	1	1	1	1		-	-	-	-					-	-						-						
Draba incana	-	-	-	-	-	-	-											-								-		-					-	-						-					
Arabis hirsuta			-	-	-						-	-	-		-								-			-														-				
Sedum acre	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	
S. reflexum	-	-						-	-	-																											1	1	1	1	1	1	1	1	1	1	
Saxifraga granulata	-	1	1	1	1	1	1	1											-																								-		
Fragaria viridis	-	-											-		-											-	-														-			
Potentilla spp.	1	1	1	1	1	1	1	2	1	1	2		1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	
Filipendula vulgaris	1	1	1	1	1	1	1	1	1	1	1		1	2	2	2	2	2	1	3	2	3	4		1	2	2	2	2	3	1	3	3	3	3		1	2	2	2	1	2	1	3	3	3	
Medicago lupulina	-	-						-	-	-	-				-										-	-	-	-	-		-	-									-	-			
Trifolium campestre	-	-	-	-	-	-	-						1		1	x	1	1		1			-		1		1		1			1		x		1	1	1		1			1		
T. repens	-	-	-	-	-	-	x	1	1	1	1		1		-	1	x									1	1	1	x					-			1	1	x							
T. arvense	-	-	-	-	-					-	-				-										-	x	1		-					1		1	1			-					
T. striatum	-	-	-	-	-	-	-								-										-	-			-	-	-		-	-				1	x	1	x	x	1			
Anthyllis vulneraria	-	-	-				-	x	-	-			1	1	2	1	1	1	1	1	1	1	-			1	1		-	x		x	1	1	1		-				-					
Lotus corniculatus	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1		x	1	-	x		1	1	1	1	1	1		1	1	1	1		x	1	1	1	1	-				x
Oxytropis campestris	1	1	1	1	1	1	1	1	1	1	1		1	x		1	1	1	1	1	1	1	1		1		1	1	1	1	1	1	1	1	1		1		-								
Vicia tetrasperma	-						-						-	-	-					-			-						-					-										
Linum catharticum	x	1		-	-	-				-	-		1	1	1	-	1	-		-	-	-	-		x			1	1	-	-	-	-	-		x				1			-	-	
Polygala spp.	-														-														-	-		-	-											
Myosotis stricta	-	1		1		1		1						1	1	1	1	1	1	1		-	-			1		-	x	x	1	1	/	x			1	1	1	1						
Prunella vulgaris	-	-	-	-			-	-	-		-		1	1	1	1	1	1	x	1	1	1	1					-	-			-	-			-	-	-							
P. grandiflora	-	-	-	-	-		-		-				-		-													-	-	-	-		-	-										
Satureja acinos		1	1	-	-	1	-	-							-		-	-			-	-	-		-								-			1	1	1		1		x		
Veronica spicata	1	1	1	1	1	1	1	1	1	1	1		-		1	x	-	-			-		-		1	1	1	1	1	1	1	1	1	1	x										
V. praecox	-	-	-	-	-		-	x	-					-	-				-	1		-	-		-	-						-	-	-	-					1	1	1		-	-
Plantago lanceolata	1	1	1	2	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	x		1	1	1	
Galium triandrum	1	-	-	x	x	-	-	-	-	-	-		1	-	x	1	1	1		x	1	1	1		-	-		-		1		-	-	-	-					-	-	-	-			
G. verum	1	1	1	1	1	1	1	2	2	2	1		1	1	1	1	1	1	1	1	2	2	2		1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	
Campanula rotundifolia		-	-	-	-	-		-	-	-					-	-	-	-	-						x	1	-	-	-	-								-	-	x		-				
Antennaria dioeca	1	1	1	1	1	1		1	1				1	1	1	1	2	1	1	1	1	1	1				-	-	-	-							-				-					
Achillea millefolium	1	1	1	1	1	1	1	1	1	1	1		-	-	-			-	-			-	-						-		-							-						
Artemisia laciniata	1	1	1	1	1	1	1	1	1	1	1		1	-				-	-	-	-						-	-	-									-						
A. campestris	1	1	1	1	1	1	1	1	-	1	-					-	-	-	-	-			-		-		-	-									-			-	-		
Taraxacum spp.	x	1	-	-	-	1	-	-	1		1			1				1	-	-						1	-		-	-			1					1	-			1		1	
Hieracium pilosella	1	1	1	1	1	1	1	1	1	1			1	1	1	1	1	-	-	-						-	-	-	-	-							1	1	1	1	1	1	1	1	1	
Dwarf shrubs																																													
Helianthemum nummularium	-	x	1	1	1	1	1	1	1	1	1		1	1	1	2	2	2	1	1	2	2	3		1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	
H. oelandicum	-	-	-		-	-	-				-		1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	
Thymus serpyllum	1	2	2	2	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	2		1	1	1	1	1	1	1	1	1	1	
Juniperus communis	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	

Scleranthus annuus plot 27: 1970(x), plot 30: 1970(1); Stellaria graminea plot 36: 1970(1), plot 38: 1970(1), plot 39:1970(1); Silene nutans plot 57: 1969(1), 1970(1), 1971(1); Erophila verna plot 30: 1970(1), plot 36: 1971(x); Saxifraga tridactylites plot 27: 1969(1); Cotoneaster integerrimus plot 57: 1974(x), 1975(x), 1979(1); Hypericum perforatum plot 57: 1978(x), plot 58: 1970(x); Viola spp. plot 39: 1969(1), plot 54: 1970(x); Euphrasia spp. plot 27: 1972(1), 1973(1), plot 38: 1972(x); Hypochoeris maculata plot 54: 1969(x), 1970(1), 1972(x). - Cover value within brackets.

le 20 (contin.)

| no. | 39 (UG, F) | | | | | | | | | | | 54 (UG, F) | | | | | | | | | | |

Table 21. Mean values of numbers of taxa for 11 years in each plot including ranges between minimum and maximum numbers.

Plot no.	27	30	36	38	39	54	57	58
No. of taxa	24.7	24.5	18.3	18.5	16.1	25.3	24.7	20.8
Range	9	8	5	9	7	4	6	7
Annuals	2.7	3.5	3.9	4.4	2.9	0.8	1.3	1.5
Range	5	4	4	7	4	2	2	3

Table 22. Mean values for number of taxa and annuals in each of the 11 years recorded.

Year	69	70	71	72	73	74	75	76	77	78	79
No. of taxa	21.0	23.9	22.9	22.6	22.8	22.3	19.3	22.5	20.0	20.3	20.3
Annuals	2.5	4.3	3.3	2.6	3.5	2.9	2.4	3.5	1.4	1.6	1.5

Table 23. Yearly mean values for numbers of taxa and annuals in fenced and unfenced grazed Festucetum plots (test plots harvested).

	Test plots					Control plots			
Year	1969	-70	-71	-72	-73	1969	-70	-71	-72
Fenced									
No. of taxa	8.0	14.3	10.3	9.3	10.3	9.0	13.3	11.3	12.0
Annuals	1.3	4.0	2.8	2.8	4.0	1.0	3.7	2.3	2.3
Unfenced									
No. of taxa	6.8	9.3	6.5	5.8	7.3	6.3	10.7	9.3	9.3
Annuals	1.0	2.3	1.5	1.8	2.8	1.0	3.0	1.7	1.7

grazed areas during dry periods of the year. Pettersson (1958 p. 139) also considers trampling to be the main changing factor in comparison with grazing itself.

In control plots in all types of sample plots there is an increase in number of taxa from 1971 to 1972. The increase in *Festucetum* (*F.*) is 25—50% but occasionally 100% or even more; for *Avenetum* (*A.*) it is 10—30% and occasionally 50% or more. This increase may be referred to climatic conditions during those two years but also to recolonization after the dry year of 1969 (Rosén & Sjögren 1973 pp. 147 ff.).

Examples of taxa in the *Avenetum* favoured after 1969 and appearing in 1972 are: *Fissidens cristatus, Rhodobryum roseum, Tortula ruralis, Thuidium abietinum, Mnium* spp., *Ptilidium ciliare*, and *Camptothecium lutescens*. From the *Festucetum* the following can be mentioned: *Barbula convoluta, B. reflexa, Riccia subbifurca, R. sorocarpa, Weisia* sp., *Bryum* spp., *Campylium* spp., *Schistidium apocarpum* and *Clevea hyalina*. These mosses also became more frequent in the test plots in 1972.

Cetraria islandica, Cladonia rangiformis, C. arbuscula were the most frequent lichens in control plots of the *A.*, both in grazed and ungrazed areas. *Camptothecium lutescens, Rhacomitrium canescens, Rhytidium rugosum* and *Thuidium abietinum* are the most frequent mosses in ungrazed *A.*, found in 50% or more of the sample plots. In grazed *A.*, *Bryum capillare, Dicranum scoparium, Hypnum cupressiforme* var. *lacunosum*, and *Rhodobryum roseum* can be added to these taxa as they are also found in at least 50% of the plots.

Fissidens cristatus is more frequent in ungrazed than in grazed *A.*, while *Ceratodon purpureus, Ditrichum flexicaule, Pohlia nutans*, and *Polytrichum juniperinum* are more frequent in grazed than in ungrazed *A.* But none of the latter taxa occur in 50% or more of the plots.

In the *Festucetum* (control plots), *Cladonia symphycarpa* is the most frequent lichen (> 50%) in ungrazed plots. In grazed plots *Cladonia* sp. and *Leptogium lichenoides* are added to *Cladonia symphycarpa* as the most frequent lichens.

Among the mosses, *Ctenidium molluscum, Ditrichum flexicaule*, and *Tortella* spp. are more fre-

quent in ungrazed plots while *Barbula* sp., *Bryum argenteum, Campylium* cfr. *elodes, Riccia subbifurca* and *Weisia* sp. may be added from grazed plots. In addition, it seems as if *Barbula convoluta, Clevea hyalina, Hypnum cupressiforme*, and *Schistidium apocarpum* are more frequent in ungrazed than in grazed *F.* although being present in less than 50% of the plots.

Both in grazed and ungrazed *A.* and *F.* the number of taxa generally increased in the subplots which had been cut for 1—3 years, while there is generally a decrease after 3—4 years of harvest. In most cases acrocarpous mosses are mainly responsible for the increase as they apparently easily expand in plots where more bare soil has become available as a result of the harvests. After a few years of harvest most of the lichens and several of the pleurocarpous mosses suffer and disappear.

As the material from these records of mosses and lichens is rather limited and only reflects a fairly short period of time (4 years), it becomes difficult to classify them according to their reactions to harvest. The problem becomes especially pronounced for the large number of taxa which were only found in a few plots. Nevertheless, some taxa seem possible to arrange in groups due to changes caused by the harvests (simulated grazing):

Avenetum

Colonizing taxa, not found in control plots: *Barbula convoluta, Bryum argenteum*, and *Bryum* sp.

Established taxa, increasing in frequency: *Bryum capillare, Ceratodon purpureus, Ditrichum flexicaule, Encalypta* sp. *Fissidens cristatus, Mnium cuspidatum, Pohlia nutans, Tortula ruralis*, and *Cladonia pyxidata.*

Established taxa, decreasing in frequency: *Camptothecium lutescens, Dicranum scoparium, Hypnum cupressiforme, Ptilidium pulcherrimum, Rhytidium rugosum, Thuidium abietinum, Cetraria islandia*, and *C. rangiformis.*

Festucetum

Colonizing taxa, not found in control plots: *Bryum neodamense, Bryum* sp.

Established taxa, increasing in frequency: *Barbula* sp., *Bryum argenteum, B. capillare, Campylium* sp., *Clevea hyalina, Ditrichum flexicaule, Encalypta* sp., *Riccia sorocarpa, R. subbifurca, Schistidium apocarpum, Tortella* spp., and *Weisia* sp.

Established taxa, decreasing in frequency: *Camptothecium lutescens, Ctenidium molluscum, Hypnum bambergeri, H. cupressiforme, Thuidium abietinum, Cetraria islandica, Dermatocarpon* sp., and *Fulgensia fulgens.*

Although not demonstrated by this material, most lichens are known to be damaged and may even disappear as a result of trampling, etc. This also applies to some of the taxa listed above, occasionally first increasing and then decreasing or even disappearing. A complication which increases the wear is that when the tufts in the *Festucetum* are destroyed by harvest the frost-induced soil movements increase, as already discussed, thus making it difficult for many of the lichens and mosses to survive. Hepatics and acrocarpous mosses, however, seem to cope with this situation quite well.

Most taxa in this investigation receive the cover value 1 (or even x) but in some cases remarkable changes occur. In sample plots nos. 35—40 (*Avenetum*, ungrazed) *Cladonia arbuscula* increased very much in the harvested plots in comparison with the control plots as a result of a rapid growth of phyllocladias. Thus, cover values increased from 1—3 to 3—5. Most surprising are the changes in subplots 35 II and 35 IV where *C. arbuscula* increases from 2 to 5 and 1 to 5 respectively from 1971 to 1972. In sample plot 51 (*A.*, ungrazed) the cover value was 5 in 1971 but only 3 in 1973. In most plots however, a permanently low value of generally not more than 1 was maintained for this species.

In many of the harvested plots *Hypnum cupressiforme* var. *lacunosum* reached much higher values than in the control plots. This bryophyte was recorded with cover values of 3 and 5 in sample plots 6 and 7 (*A.*, grazed) respectively (1971). Then it gradually decreased to 1 in both cases (1974). *Hypnum cupressiforme* in plots 27 and 28 (*A.*, grazed) got a value of 5 in 1971 and then decreased. *Hypnum* often grows in patches in the mosaic alvar vegetation and probably such patches expanded marginally when competition decreased due to the cuts. These patches seem to decrease in size when vegetation becomes more dense. In most plots *Hypnum* received 1 in the cover scale.

Bryum capillare in plots 4 and 5 (*A.*, grazed) increased from cover value 1 to 3 and then decreased. In many other plots it occurred with cover value 2. *Ceratodon purpureus* generally received 1, but in subplots 3 II and 3 IV (*A.*, grazed), it increased from 1 to 4 and 1 to 3 respectively from 1971 to 1974.

Tortella spp. seem to have increased in some plots of the *F.* from cover value 2 to 3, and in other plots *Schistidium apocarpum* increased from 1 to 3 (even 4 in one case) and then decreased.

In addition to the information given above, Steen (1956 p. 103) demonstrated in an *Avenetum* area on Öland that, e.g., *Barbula* spp., *Bryum* spp., and *Encalypta* sp. increase and lichens disappear when grazing intensity is increased. Bjarnason (1979 p. 46) points out that, e.g., *Barbula* spp., *Ceratodon purpureus, Ditrichum flexicaule, Schistidium apocarpum*, and *Tortella tortuosa* may be used as indicator species for overgrazing in Iceland. Ljung (1970 p. 33) also points out that some of these mosses increase in heavily-grazed alvar areas, e.g., folds. She mentions *Bryum argenteum, Bryum* sp., *Pohlia nutans*, and *Ceratodon purpureus* as taxa which seem to withstand the wear best. Less resistant in that respect are the bryophytes *Ditrichum flexicaule* and *Schistidium apocarpum*.

4 Fertilization experiment

The question of improvement by fertilizer arose during discussions on the productivity of the Alvar. The Swedish National Environment Protection Board indicated interest in an experiment providing information on consequences for vegetation following fertilizer application. A small scale experiment was started to provide information on productivity increases and also whether there were serious changes in the composition of the vegetation which might effect groups of taxa valuable from a conservancy viewpoint.

4.1 Methods

Due to limited time it was decided to conduct a small fertilization experiment only in the *Avenetum*-vegetation. An area of *Avenetum*, as homogeneous as possible, sufficient for 40 sample plots was chosen. The system of plots was arranged in 4 rows each with 10 plots. Around all plots a zone of 0.4 m was left to avoid interference from neighbouring plots and also to be used as paths between the plots. The area was enclosed.

An NPK fertilizer (13-10-13) was distributed according to the following plan: (1) unfertilized (control), (2) 20 g/m^2 in two applications/year, (3) 40 g/m^2 in two applications, and (4) 60 g/m^2 in two applications. The plan was laid out with 10 randomized replicates, 1 m^2 each. The fertilizer was applied in spring (May) and again after the first cut (August/September), with half the dose each time.

On the first occasion (1970), the fertilizer was spread out in granulated form. As it took some time for the pellets to be dissolved during a long period of drought, and as they consequently could not become available to the vegetation in the plots, it was decided to dissolve them in distilled water (0.4 l/m^2) before application in late August 1970. The same amount of water was also supplied to the unfertilized control plot to compensate for an irrigation effect in the fertilized plots. The same procedure was repeated in 1971 and 1972. The dissolved fertilizer was evenly spread over the plots with a spray bottle.

Records of all taxa (apart from mosses and lichens) and their cover values were made in all plots in mid August 1970 and early September 1972. The cover values were graded according to a 5 degree scale (Hult-Sernander-Du Rietz).

The plots were harvested to obtain production values (standing crop). Only the central 1/4 m^2 was cut to avoid too severe disturbance by the border effect. This was done during a few days in August-/September and in November/December each year, except during the autumn 1971 (see below). The plants were cut off at about 1.5 cm above ground to avoid disturbances in regeneration and in the composition of the vegetation. The standing crop was dried and weighed as described in 3.1.2.

In 1970 and in 1972 the summer crops were separated into three components: graminids, herbids and dwarf shrubs (cf. 3.1.3).

The standing crop of 1972 was analyzed for digestibility, crude protein, nitrogen, and metabolizable energy, to find out whether there were differences between the plots.

After the last harvest in November 1972, a soil sample was taken from each plot. The soil from each level of supplied fertilizer was mixed and homogenized. Two sub-samples from each level were then analyzed at the National Swedish Laboratory for Agricultural Chemistry, Uppsala, for contents of organic matter (humus), total nitrogen (Kjeldahl-N), P, K, organic carbon, and pH.

4.2 Results

4.2.1 Standing crop

There was a rather small response in the vegetation to the fertilizer in the first year, to some extent due

Table 24. Mean values of standing crop (g/m^2) for different applications of fertilizer (NPK) in 1970-72 (0,20,40 and 60 g/m^2 of fertilizer per year in two applications, half dose each time). Harvests in August/September and November/December. No harvest in autumn 1971 because of extreme drought. - Alvar of Nedre Ålebäck.

Treatment		0	20	40	60
1970	Summer	130	120	152	158
	Autumn	23	29	27	37
	Total	154	149	178	195
1971	Summer	72	105	168	225
1972	Summer	117	168	269	368
	Autumn	9	20	34	43
	Total	126	188	303	411

Table 25. Percentage increase or decrease of standing crop due to treatment with fertilizer (g/m^2) during 1970-72, in each case related to control plots. For details in fertilizer treatments see Table 24. - Alvar of Nedre Ålebäck.

Treatment		20	40	60
1970	Summer	-8	16	21
	Autumn	23	16	59
	Total	-3	16	27
1971	Summer	46	134	212
1972	Summer	44	130	216
	Autumn	112	263	253
	Total	49	140	226

Table 26. Summer values of standing crops (g/m^2) 1970 and 1972 for graminids, herbids, and dwarf shrubs in relation to supplied amount of fertilizer (g/m^2). Harvested in August/September each year. For details in fertilizer treatments see Table 24. - Alvar of Nedre Ålebäck.

Plant group	Graminids		Herbids		Dwarf shrubs	
Year	1970	1972	1970	1972	1970	1972
0	73.0	63.3	34.0	30.4	23.4	23.0
20	73.0	115.7	29.2	30.3	18.1	21.7
40	84.9	194.0	42.1	51.2	21.4	23.5
60	96.5	294.9	36.8	55.0	23.8	18.4

Table 27. Percentage increase or decrease in standing crops for graminids, herbids, and dwarf shrubs from 1970 to 1972 in relation to supplied amount of fertilizer. For details in fertilizer treatments see Table 24. - Alvar of Nedre Ålebäck.

Plant group	Graminids	Herbids	Dwarf shrubs
0	-13	-11	-2
20	59	4	20
40	129	22	10
60	206	50	23

Table 28. Percentage of graminids, herbids, and dwarf shrubs of the summer standing crops (g/m^2) in 1970 and 1972 in relation to supplied amount of fertilizer (g/m^2). For details in fertilizer treatments see Table 24. - Alvar of Nedre Ålebäck.

Plant group	Graminids		Herbids		Dwarf shrubs	
Year	1970	1972	1970	1972	1970	1972
0	56	54	26	26	18	20
20	61	69	24	18	15	13
40	57	72	28	19	14	9
60	61	80	23	15	15	5

to the undissolved pellets. The response increased in the second year and became remarkably high in the third year. The crops for the three years are given in Table 24.

In 1970 it appears that the highest fertilized plots (60) have markedly higher values than the others, both in summer, autumn and totally. For the other 20- and 40-plots, the increase is less clear. The 20-plots even show lower values than the control plots, for some unknown reason. However, in 1971 there is a clearly increasing trend with higher doses of fertilizer. In that year, however, no autumn harvest was taken as the production was almost negligible due to lower amounts of precipitation in August-November than normal.

In 1972 there was an increase in the fertilized treatments resulting in production increases several times those of the control plots. The values of the control plots decreased from 1970 to 1971, and then increased again from 1971 to 1972, as also did the 20-plots. Whether this depended on climatic differences between years or effects of harvests is unknown, but the very low precipitation (195 mm) in April—September in 1971 might be a reason (cf. 1.3.1 Table 3). Nevertheless, the 60-plots had an accumulated increase from 1970 to 1972 (195 to 411 g/m^2).

Using the control plots as a zero-value at each time of harvest, it is possible to calculate the percentage increase (or decrease) on the fertilized plots (Table 25). In 1970 the increase for the 60-plots was only 27%, but in 1972 it was 226% higher. Percentage values for the summer of 1971 gave almost the same proportions as for the summer of 1972, indicating that the relative difference between treatments was obtained already in 1971, even though the absolute figures increased until 1972. A rapid change has taken place. For autumn values the differences are more pronounced.

Results of the separations into different components (graminids, herbids, and dwarf-shrubs) for the summer standing crops of 1970 and 1972 are shown in Table 26. In 1970 there was a rather weak increase of graminids with increased amounts of fertilizer, but for herbids and dwarf-shrubs no trends were distinguished. However, in 1972 there was a strong increase of graminids, a weak increase of herbids but no clear change of dwarf-shrubs except for a decrease in the 60-plots. The

values of the control plots were somewhat lower in 1972 than in 1970 but there are no drastic differences. The changes of graminids in the fertilized plots are more pronounced.

Table 27 presents the differences between the two years in percentage values. The most pronounced difference is seen for the graminids which increased 206%, while the herbids increased 50%, and the dwarf-shrubs decreased 23% in the 60-plots. Dwarf-shrubs might have been somewhat favoured in the 20-plots by fertilization and moderate competition.

A comparison of the percentage composition during 1970 and 1972 for the different components and treatments shows a different result to the absolute values (Table 28). In 1970 the control plots show the natural, undisturbed composition of the vegetation with graminids making up 56%, herbids 26%, and dwarf shrubs 18%. The 1972 values for the control plots (54%, 26%, and 20%) indicate no severe disturbances to the experiment caused by the cuttings. Very small differences were found in the other treatments (fertilization) in 1970 in comparison with the control plots. In 1972 the share of graminids increased but for herbids and dwarf-shrubs the shares in the fertilized plots decreased. The new composition of the vegetation in the 60-plots was 80% graminids, 15% herbids, and only 5% dwarf-shrubs. This means that graminids are favoured while herbids and especially dwarf-shrubs are suppressed by the increased graminid competition caused by the fertilizer.

An analysis of the material obtained from the records of taxa in 1970 and 1972 indicates what might have caused above-mentioned changes in the composition of the vegetation. These data are presented in Table 29. There are small differences in numbers of taxa recorded for the two years due to different treatments (Table 30). Mean values show a small increase in the total number of taxa in all groups from 1970 to 1972. A small increase of herbids is mainly responsible for this, as there is no significant change in number of graminids or dwarf-shrubs related to any of the different levels of supplied fertilizer. But these changes for herbids are very small and may be within the range of variation from one year to another. In addition, most taxa in the *Avenetum*-vegetation are herbids and thus wider fluctuations in the number of taxa may occur among them. A long-term prediction of the development cannot be made on the basis of these figures.

To elucidate changes in cover values for specific taxa, a further analysis of Table 29 was made. The most remarkable change was for *Festuca ovina*, showing a very clear increase in cover values, being the more pronounced with increasing amounts of fertilizer supplied (Fig. 13). The cover values show an unchanged proportion for *Festuca ovina* in control plots from 1970 to 1972. In the 20-plots there is a general change from cover values of 1—2 in 1970 to 2—3 in 1972, in 40-plots from 1—2 to 3—4 and in 60-plots from 1—2 to 4—5. *Festuca ovina* dominates in the latter plots, forming a dense sward, which is also higher than in control plots.

Among other graminids, a small increase in occurrence is recorded for *Anthoxanthum odoratum* in the fertilized plots. *Sieglingia decumbens* shows a small increase of cover in the control and 20-plots, while *Briza media* seems to increase in fertilized plots. Most of the graminids show fairly persisting cover-values and a regular occurrence in all sample plots; the same also applying to many of the herbids, e.g., *Potentilla* spp., *Filipendula vulgaris, Prunella grandiflora, Plantago lanceolata, Galium verum, Antennaria dioeca, Achillea millefolium*, and *Hieracium pilosella*.

In the fertilized plots, *Cerastium glutinosum* fre-

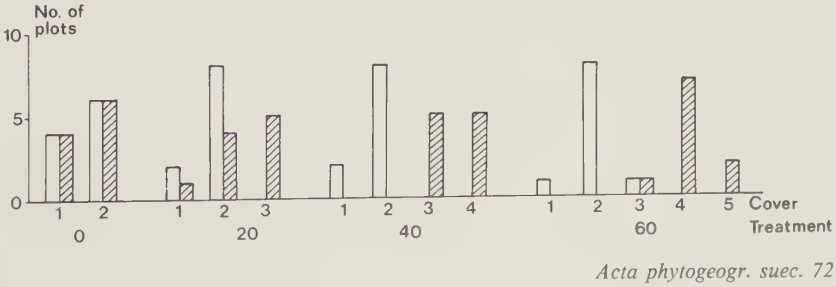


Fig. 13. Changes in cover values for *Festuca ovina* from 1970 to 1972 in sample plots after various treatments with NPK (g/m²/year). (Cover values according to a five degree scale, see 3.1.1; 1970 = unshaded, 1972 = shaded). — Alvar of Nedre Ålebäck.

Table 29:1. Records of taxa and their cover degrees in permanent sample plots in Avenetum vegetation treated with different applications of fertilizer (NPK) in 1970-72 (0, 20, 40, and 60 g/m^2 of fertilizer per year, two applications, half dose each time). Records were done in mid August 1970 (a) and early September 1972 (b).

Table 29:2. Total, mean, highest, and lowest number of taxa for each treatment and category (graminids, herbids, dwarf shrubs, total) are given for 1970 and 1972. Cover values are according to the 5 degree scale of Hult-Sernander Du Rietz (cf. 3.1.1). - Alvar of Nedre Alebäck.

	(0)																				(20)																					
	1		4		5		8		16		17		18		25		27		33		9		12		15		19		20		22		24		29		35		36	
	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b	a	b
Graminids																																										
Anthoxanthum odoratum	1	-	x		-	-	x		-	-	-	-	1	-	-	1		1			x	1	1	x	x	1	1	1	-	1	1	-	1	1	-	1	-	-	-	1		
Phleum phleoides	-	-	-	-	-	-	1	1							-		-	-			-	-	-	-	x	-			-	-	1	1									-	
Agrostis tenuis	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1
Arrhenatherum pratense	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	2	1	1	1	2	2	2	1	1	1	2	1	1	1	2	1	2	2	1	1			
A. pubescens	1	1	-	1	1	1	-	1	-	1	-	1	1	x	x	1	1	x	-	-	1	1	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1		1			
Sieglingia decumbens	1	1	1	1	1	1	1	2	1	2	1	2	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	2	1	2	1	1			
Sesleria coerulea ssp. uliginosa	-		-		-		-		-	-							-	-	1	1	-	-			1	1		-	1	1	1	1		-	-				-	-		
Briza media	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1		
Festuca ovina	1	1	2	2	2	2	2	2	1	1	1	1	1	1	2	2	2	2	2	2	2	3	1	2	2	3	2	3	2	1	2	3	2	3	1	2	2	2	2			
Carex ericetorum	2	2	1	1	1	1	1	2	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
Luzula campestris	1	1	-	x	x	-	1	1	1	-	1	1	1	1	1	1	1	x	1	1	x	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
Herbids																																										
Orchis sp.	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Scleranthus annuus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Arenaria serpyllifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Stellaria graminea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-		
Cerastium glutinosum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	x	-	-	-	x	1	1	-	1	-	1	-	1	-	1	-	1	x	1	-	x	-	1				
Ranunculus bulbosus	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	x	x	x	-	-			
Anemone pratensis	-	-	-	-	-	-	-	-	-	-	x	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-				
Arabis hirsuta	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-				
Sedum acre	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-				
Fragaria viridis	-		-		-		-		-		-		-		-		-		-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				
Potentilla spp.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
Filipendula vulgaris	1	1	1	1	1	1	1	1	2	2	1	1	1	1	1	1	1	1	2	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
Medicago lupulina																																											
Trifolium campestre	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
T. repens										1				-							-		1	1	-	-		-	-	-		-	-			1	1	-	-	-		
T. pratense	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-				
T. arvense	-	-						-																	-	-		-	-	-	-	-	-	-	-	-	-	-				
Anthyllis vulneraria	x	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	x	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
Lotus corniculatus	-	-	x			1			x	1	x	1	1	-	1	x	-	-			1	1	-	1	-		1	1	1	-	1	1	1	1	-	-	-	1			
Oxytropis campestris	1	1	-	1	1	1	x	x	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	-	1	1	1	1	1	1	-	-	x	1	1	1	-	-	1	1		
Linum catharticum	x	1	1	1	x	1	1	1	1	1	x	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	x	1	1	1	1	1		
Polygala vulgaris	-	-	-	-	-	1			x		-	-	1	-	x			x			1		-	-	1	-	1	1		-	-		-	-	1		x	-	1		
Viola sp.	-	-			1		1	x	x	x	1	x	1	x	1						x		-		x		-	-	x		-		1	1	x	x		-			
Prunella grandiflora	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
Veronica spicata	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	1	1	1	1	x	1	1	1	1	1	1	1	x	1	1	1	1	1		
Euphrasia sp.	x	1	1	1	1	1	x	x	x	1	1	1	1	1	1	1	1	1	1	-	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	x	-	1	1		
Globularia vulgaris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Plantago lanceolata	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	x	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
Galium triandrum	1	1	x	1	1	1	1	1	1	1	1	1	1	-	1	1	1	1	1	1	1		1	-	1	1	x	-	x		1	1	1	1	1	1	1	1	1	1		
G. boreale		1	1	1	1	1	1	1	-	-	-	-	1		-		-		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	-	1	1	1	1		
G. verum	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
Scabiosa columbaria		1	1	1					-	1	-	-	-	1	-	1	x	1	-	-	-	1	1	1	1	x	-	x	-		x	x	1	-	-	-	1	-	-		
Campanula rotundifolia	1	1		1		-	1	1	1	1	x	1	x	1	-	x	-	x	1	1	-		1	1	-		-	x	1	-	1	1	1	1	1	1	1	1	-	-		
Antennaria dioeca	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-		1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	1	1		
Achillea millefolium	1	1			1	1	1	1	x	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
Artemisia laciniata		-		-	-	1	1	-	-	-	-	-	-	-	-	-					-				-	-	-	-	-	-	-	-	-	-	-	-	-	-				
A. campestris	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-		-	-	-										-	-		
Senecio jacobaea ssp. gotl.	1	-	-	-	x	x	-	-	1	1	-	-	-	-	1	1	-	-	-	-	-	-	-	-	1	x	-	-	-	-	-	-	1	1	-	-	-	-	-	-		
Carlina vulgaris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-			-			1			-	-			-	-	-	-	1	-			-			
Cirsium acaule	-	-	2	2	-	-	1	1	-	-	1	1	1	1	-	-	1	1	1	1	1	1	1	1	1	-	-	1	1	1	1	1	1	x	x	1	1	1	1	-	-		
C. arvense	-	-	-	-	-	x	-		-	-	-	1	1	-	-							1	1		-	-	-		-	-	-	-	1					-	-		
Centaurea jacea	1	1	1	1	1	1	-	-	1	1	1	1	1	1	-	-	1	1	1	1	1	1	1	1	-		-	-	-	-	1	1	1	1	1	1	1	1	-	-		
Taraxacum sp.	-	1	1	1	x	1	1	1	x	1	1	1	x	1	1	1	-	1	-		1	1	-	-	1	1	x	x	x	x	1	1	1	1	x	1	x	1	-	1		
Hieracium pilosella	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
Dwarf shrubs																																										
Helianthemum nummularium	3	3	1	3	1	2	1	2	1	2	2	3	2	3	1	2	1	1	2	2	1	2	1	2	1	2	2	2	1	2	1	2	1	2	1	1	1	2				
H. oelandicum	1	1	-		-	-	-		1	1	x		-	-	1	1	1	1			-		1	1	1	1		-	x	1	1	1			-	-	-	-				
Calluna vulgaris	1	1	1	1		1			1	1	1	1	x	1	-	1	1	1	1	x	1	1	2	2	x	1	1	1	1	1	-	1	1	2	2	1	1	-	-			
Thymus serpyllum	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
Juniperus communis	-	-	1		-	-	-	-	-	-	1		-	-	-	-		x			-	-	-	-	-	-	-	-	-	-	-	-	1	-		-					

Table 29:2.

Plant group		Graminids				Herbids				Dwarf shrubs				Total			
Treatment		0	20	40	60	0	20	40	60	0	20	40	60	0	20	40	60
1970	Highest no. of taxa	9	10	9	10	22	24	23	22	4	4	4	4	34	36	36	33
	Lowest no. of taxa	7	6	7	7	17	15	17	17	2	2	2	2	28	23	27	29
	Mean no. of taxa	8.2	8.7	7.9	8.4	18.9	18.9	19.5	19.6	3.4	3.4	3.1	3.0	30.5	31.0	30.5	31.0
1972	Highest no. of taxa	9	10	10	10	24	26	26	23	4	4	4	4	35	38	37	35
	Lowest no. of taxa	6	8	8	8	19	19	18	18	2	2	2	2	30	30	29	29
	Mean no. of taxa	7.7	9.2	8.8	9.0	21.0	21.6	20.9	20.5	3.3	3.2	3.0	2.7	32.0	34.0	32.7	32.2

| | (40) | | | | | | | | | | | | | | | | | | | | (60) | | | | | | | | | | | | | | | | | | |

quently increases in occurrence and seems to be favoured, *Ranunculus bulbosus* shows a slight increase, while *Anthyllis vulneraria* and *Linum catharticum* decrease in these plots. The *Linum* species seem to have a particularly weak competitive ability in the thick vegetation sward of these plots. *Polygala vulgaris* increases in all types of plots, possibly as a result of fluctuations from one year to another. Such fluctuations may also be responsible for variations in occurrence and cover values for other taxa. In the control plots there is also an increase in occurrence for *Scabiosa columbaria*.

Among the dwarf-shrubs, *Helianthemum nummularium* shows increased cover values in the control plots, but only small increases in the fertilized plots except in the 60-group where no change was noticed. The increase in cover value for *Helianthemum nummularium* is probably due to a better ability to adopt a more prostrate growth-form as a consequence of the cutting. A more erect form is adopted in the dense plant cover which is established in the 60-group. This situation gives a higher cover value in the first case although the standing crop could be almost the same as in the older plots. *Helianthemum oelandicum* has also a tendency, although very uncertain, to decrease in cover in the 60-group, which fits the picture of its preferred habitat, i.e., sparse vegetation (*Festucetum*). *Thymus serpyllum* has the most regular occurrence among the dwarf shrubs.

In addition *Orchis* sp. in the 40-group might have been eliminated by the dense vegetation. An interesting taxa found in the experimental plots is *Senecio jacobaea* ssp. *gotlandicus*, which is fairly rare in the Alvar area (Sterner 1938 p. 126; Lundqvist 1979 pp. 320 ff.).

Chapter 3 discusses variations in cover or occurrence from one year to another. No further changes in composition should be discussed in this material, as these records were made on only two occasions in a limited number of plots over a short period of time.

An investigation by Willems (1980 pp. 279 ff.) shows results very similar to mine. A fertilizing test was established in an abandoned calcareous grassland (Dutch province of Limburg) with the plant association *Arrhenatheretum elatioris*. In permanent plots he found an increase in number of taxa (1971—78) for unfertilized plots and a decrease for fertilized ones, with less taxa permanently present for the latter. Yearly harvests (August) showed values for above-ground biomass more than twice as large for the highest fertilized plots than for control plots. Graminids became dominant with *Dactylis glomerata* as most favoured taxa. Graminids increased to 75—90% (weight) from values less than 50%. The annual production was 150—350 g/m^2 for unfertilized and 550—900 g/m^2 for fertilized plots.

Increased proportions of graminids in poor natural pastures by fertilization were demonstrated by Giöbel & Steen (1960 pp. 9 ff.). They also obtained more than doubled standing crops with different treatments of NPK, and changed proportions in the vegetation composition. Dwarf shrubs decreased while graminids and herbids increased. In the latter *Leguminosae* increased. Fertilized pastures became preferentially grazed as the palatibility increased compared with unfertilized areas.

Further information on changes in the composition of vegetation following fertilization is given, e.g., by Jones (1967 pp. 66 ff.) for hill pastures in Wales, and by Traczyk et al. (1976 pp. 39 ff.) and Traczyk & Kotowska (1976 pp. 75 ff.) for meadow vegetation in Poland.

4.2.2 Chemical analysis of standing crop

There were drastic changes in productivity and composition of the vegetation caused by fertilizing, as shown above. As it was important to know whether changes in chemical composition occurred within the standing crop as a result of an increased supply of fertilizer, analyses of digestibility, metabolizable energy, crude protein, and total content of nitrogen (tot.-N) were made on the standing crop.

As the standing crops from the summer harvests in 1972 were separated into graminids, herbids, and dwarf shrubs, it was possible to analyse these components separately. A pooled sample for each component, at each fertilizing level, was created by combining crops from the 10 replicates. From the pooled sample two subsamples were taken for the analyses. In the autumn-cut standing crop no separation into plant categories was done and there were thus only 4 pooled samples, from each of which two subsamples were analysed.

The analyses were done at the National Swedish Laboratory for Agricultural Chemistry and by the Department of Plant Husbandry at the Swedish University of Agricultural Sciences, Uppsala. Conventional methods of the analysis were used. For detailed information about the calculations of digestibility and metabolizable energy by the in vitro method, see den Braver (1969). The results of these analyses are presented in Tables 31—34. Digestibility and energy were calculated for organic matter (OM). Total nitrogen content (Kjeldahl) was calculated by dividing the crude protein value by the factor 6.25.

The summer harvests of 1972 (Table 31) reveal that graminids have lower amounts of crude protein at all four fertilizing levels than herbids and dwarf shrubs. Consequently, the same applies to the total nitrogen content. The low crude protein content in the graminids might be explained by the late time of harvest. Graminids contain much larger amounts of crude protein in spring and early summer, sometimes reaching double the level measured in this experiment (cf. Steen 1968 p. 18).

The content of crude protein is higher for all plant categories in unfertilized plots than in fertilized ones. The clearest decrease following supply of fertilizer was shown by the herbids. Digestibility is highest for graminids and herbids, showing clear decreases with increasing amounts of fertilizer for both graminids and herbids, but not for dwarf shrubs. The digestibility of dwarf shrubs is probably lower as a consequence of their high lignin content. Also, the decreasing digestibility of graminids and herbids with increased supply of fertilizer in this experiment, might be a consequence of, for example, faster growth causing higher content of structural carbohydrates. As the energy content is calculated from the digestibility the same trends are shown for these figures.

In Table 32 the values are not separated into plant categories. Values from this standing crop, November 25—27, 1972 show no clear relationship with fertilization increments.

By weighting the values in Table 31 in relation to percentage content of the three components (Table 28), values comparable to those in Table 32 have been received for summer standing crops (Table 33). The amount of crude protein, and thus also the total nitrogen content, shows a clear decrease with increased supply of fertilizer in the summer crops. This decrease could be referred to a larger amount of graminids, with low crude protein content, in the actual composition of the vegetation (cf. Tables 28 and 31). However, the decreased digestibility (see Table 31) in connection with increased amounts of fertilizer is here somewhat compensated by the increased amount of graminids with their high digestibility. Nevertheless, a weak decrease can be distinguished in Table 33. Thus, the content of metabolized energy is subject to the same trend.

The values for digestibility and energy content are slightly higher for the summer crops (Table 33) than for the autumn crops (Table 32). This is reflected in the decrease of crude protein content to-

Table 31. Crude protein, digestibility, metabolizable energy, total nitrogen, ash, and dry matter content in crops of plant categories following treatment with fertilizer. Harvested on September 13-16, 1972. For details of fertilizer treatments, see Table 24. (DM = dry matter %, OM = organic matter %, Tot.-N = total nitrogen % by Kjeldahl.) - Alvar of Nedre Alebäck.

	Treatment (g/m²)	DM (%)	Ash (%)	Tot.-N (%)	Crude prot.(%)	Digest. OM (%)	Energy (Mcal/kg)
Graminids	0	97.7	6.3	1.49	9.3	64.3	2.3
Herbids	0	93.3	9.3	1.95	12.2	62.8	2.3
Dwarf shrubs	0	93.3	7.6	2.30	14.4	51.8	1.8
Graminids	20	95.2	6.1	1.33	8.3	62.7	2.3
Herbids	20	93.4	9.6	1.78	11.1	63.0	2.3
Dwarf shrubs	20	93.6	7.3	1.95	12.2	54.9	1.9
Graminids	40	95.8	5.4	1.33	8.3	61.1	2.2
Herbids	40	93.8	9.7	1.71	10.7	62.2	2.2
Dwarf shrubs	40	93.4	7.3	2.02	12.6	54.3	1.9
Graminids	60	96.4	5.0	1.34	8.4	59.3	2.1
Herbids	60	94.1	9.6	1.62	10.1	59.7	2.1
Dwarf shrubs	60	93.9	7.5	2.00	12.5	52.7	1.8

Table 32. Digestibility, metabolizable energy and dry matter content in standing crops following treatment with fertilizer. Harvested on November 25-27, 1972. For details of fertilizer treatments, see Table 24. (OM = organic matter) - Alvar of Nedre Alebäck.

Treatment (g/m²)	Dry matter (%)	Digestibility OM (%)	Energy (Mcal/kg)
0	94.3	56.1	2.0
20	94.5	58.0	2.1
40	94.5	57.3	2.0
60	94.7	54.7	1.9

Table 33. Digestibility, metabolizable energy, crude protein and nitrogen content (tot.-N) in the summer crop 1972 following treatment with fertilizer (g/m²). Harvest on September 13-16. These values were obtained after calculations with percentage content of graminids, herbids and dwarf shrubs in relationship to their values in Tables 28 and 31. For details of fertilizer treatments see Table 24. (OM = organic matter) - Alvar of Nedre Alebäck.

Treatment (g/m²)	Crude prot. (%)	Tot.-N (%)	Digestibility OM (%)	Energy (Mcal/kg)
0	11.1	1.77	61.4	2.2
20	9.3	1.49	61.7	2.2
40	9.1	1.46	60.8	2.2
60	8.9	1.42	59.0	2.1

Table 34. Standing crop (kg) and energy content (Mcal) per hectare for summer, autumn and total following fertilizer treatment (0, 200, 400, and 600 kg/ha) in two applications per year, half dose each time. Harvest in September and November 1972. (OM = organic matter, stg.cr. = standing crop) - Alvar of Nedre Älebäck.

	Summer		Autumn		Total	
Treatment	Stg.cr.	Energy(OM)	Stg.cr.	Energy(OM)	Stg.cr.	Energy(OM)
0	1170	2583	90	179	1260	2762
200	1680	3728	200	413	1880	4141
400	2690	5867	340	693	3030	6560
600	3680	7764	430	831	4110	8595

wards the autumn, appearing even if there is a higher percentage of graminids in the samples for autumn crop (cf. 8.1.2).

If a harvesting system with two very late cuts is practised, fertilizing obviously does not improve the quality of the standing crop. However, the increased productivity in the different plots results in increased total amounts of crude protein and metabolizable energy. There is roughly three times as much metabolizable energy available in the plots with the highest supply of fertilizer in comparison with the unfertilized control plots. This is shown for summer, autumn and totally in Table 34, calculated per hectare. Of these amounts, around 90% originates from the crops in September and 10% from those in November.

The effect of fertilizer treatment upon a fairly mixed vegetation at that time of the year, including both very old and young plant material, makes interpretation of the data in the Tables rather hazardous. Increased quality of the herbage, e.g., increased amounts of crude protein, would have been expected as a result of the fertilizer treatment, as demonstrated for four grass species at the grazing stage by Steen (1968 p. 18). The values obtained in the present experiment may be partly explained by the late harvests and fairly low doses of fertilizer.

4.2.3 Soil analyses

Soil samples were taken in the plots after the last harvest in November 1972. Two samples were taken in each of the 40 plots with a cylinder to a depth of five cm, roughly corresponding to the humus layer.

After removal of roots the soil was sieved through a screen with a mesh size of 2.0 mm. Pooled samples were formed by combining all samples from each level of fertilizer. They were homogenized before analysis. Two sub-samples from the pooled samples were analysed from each of the fertilizer treatments. The analyses were done at various departments of the Swedish University of Agricultural Sciences, Uppsala.

The samples were classified as sandy soil. The organic matter (humus) varied. Mean values from the two subsamples are shown in Table 35. The soils of the area are slightly acid as they generally contain fairly large amounts of silicate material. There was no significant difference in pH between the different fertilizer treatments.

The organic matter is higher in the fertilized plots than in the control plots, probably due to increased root production and litter from the increased biomass as well as an increased decomposition rate. Consequently, the organic carbon content also increases with increasing amounts of organic matter. There is a slight difference between the control plots (5.7%) and the most heavily fertilized ones (6.6%). The increased amount of organic matter facilitates the binding of water and nutrients in the soil to colloidal particles. Probably there is an accumulation of nutrients in the soil which has taken place during the years of the investigation.

For total nitrogen there is a small increase which may also be related to the increase of organic matter in the soil. Most of this nitrogen is probably bound in the organic matter as supplied fertilizer

Table 35. Analyses of soil samples from various treatments with fertilizer (0, 20, 40 and 60 g/m^2). Fertilizer was applied twice a year (half dose each time) during 1970-72. Samples were taken in November 1972 after the last harvest. - Alvar of Nedre Älebäck.

Treatment	pH-H_2O	P-AL	K-AL	P-HCl	K-HCl	org. C	tot.-N	OM
0	6.2	1.0	16.8	24	118	5.7	0.50	12-20
20	6.1	1.8	22.0	27	153	6.3	0.51	20-40
40	6.3	2.9	25.8	29	153	6.2	0.53	20-40
60	6.2	5.3	36.3	32	170	6.6	0.54	20-40

P and K are given in mg/100 g air-dried soil. Organic carbon (org. C), total nitrogen (tot.-N) and organic matter (OM) are given in percent. For plants easily soluble P and K are calculated by the AL-method and difficultly soluble P and K by the HCl-method (cf. text).

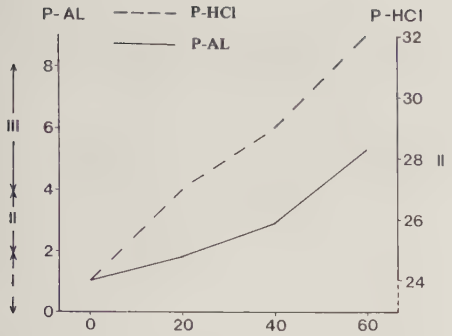


Fig. 14. Contents of P-AL and P-HCl (mg/100 g air-dried soil) in soil samples (November 1972) from various treatments of fertilizer (g/m^2), see text. (II—III refers to class by Ståhlberg 1976.) — Alvar of Nedre Ålebäck.

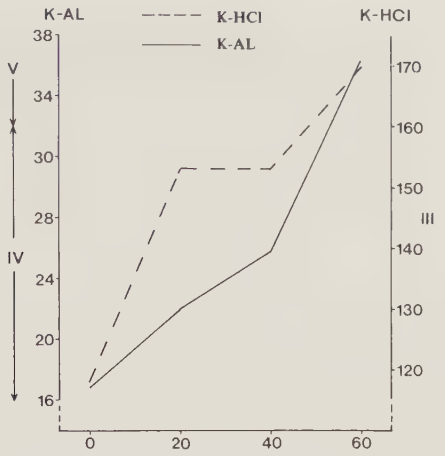


Fig. 15. Contents of K-AL and K-HCl (mg/100 g air-dried soil) in soil samples (November 1972) from various treatments of fertilizer (g/m^2), see text. (III—V refers to class by Ståhlberg 1976.) — Alvar of Nedre Ålebäck.

has been taken up by the plants and will be released by decomposition. A large part of the supplied nitrogen has been removed from the cycle by the harvests.

There is still some doubt about the availability of P and K to plants, and how it can be measured. Various methods concerning these problems are discussed by Ståhlberg (1980 pp. 93 ff.).

In this experiment, analyses of easily soluble (available) P and K were done according to the Swedish AL-method (Egnér et al. 1960). For difficultly soluble (stored) P and K the HCl-method was used (op. cit.). In the following discussion these units are referred to as P-AL, K-AL, P-HCl and K-HCl. These two kinds of P and K are classified into five levels by Ståhlberg (1976 p. 11). A higher value gives a higher class. Compared with these classes, the value of P-AL for the control plot (1.0) falls into class 1 and the value of K-AL (16.8) falls into class 4, indicating that there is a very low content of P-AL available to the plants, but a fairly high content of K-AL in the soil at that time of the year. There is obviously a trend towards increasing values due to the higher supply of fertilizer. The largest amount of P-AL (5.3), found in the highest fertilized plots, reaches class 3, and that of K-AL (36.3) reaches class 5. For P-HCl and K-HCl the values from the control plots fall into class 2 for P-HCl and into class 3 for K-HCl. Values remain within these classes even after increased supply of fertilizer (cf. Figs. 14 and 15).

The results discussed above show that fertilizing primarily improved the supply of P-AL and K-AL. Values obtained also suggest that supply of a fertilizer with higher P contents than the one used, might have been preferable as K does not seem to be the limiting factor it was supposed to be. However, as the main part of P in the soil is available it might already have been used by the plants, and thus would not be shown in the figures. In this connection, Bengtsson & Kristiansson (1966 p. 129) mention that a low pH-value in the soil might cause a decrease in the proportion of P-AL as P could be bound in difficultly soluble compounds, as is commonly found in soils poor in calcareous material. Such bindings might have taken place in the present case as the locality for the fertilizing experiment, with sandy gravelly deposits overlying limestone rock, has a low content of calcareous material, at least in the upper part of the soil. This is also shown by the pH-values (6.1—6.3), which are lower than the value of pH 6.5 which is considered the most favourable (Ståhlberg 1976 pp. 10 ff.). No soil analyses were made from deeper layers of the soil.

4.2.4 Soil samples from grazed and ungrazed alvar areas

Soil samples for analyses were taken from various alvar areas to be compared with those of the fertilization experiment. Most of the samples originate from sites with *Avenetum* vegetation influenced by sheep grazing. One site was in grazed and one in

Table 36. Analyses of soil samples from the humus layer in different sites on the Stora Alvaret, ungrazed or influenced by sheep grazing to different extents. Samples are taken on September 6-9, 1973. For comparison, values from control plots (CP) of the fertilizing experiment (Table 35) are added.

Site	Veg.	pH	P-AL	K-AL	org.C	tot.-N	OM
I	F G	7.6	3.1	135.0	11.8	1.23	20-40
II	F UG	7.3	1.2	21.3	8.7	0.84	20 40
III	A G	6.2	1.4	24.0	6.4	0.55	12-20
IV	A G	6.6	28.7	129.0	7.1	0.62	12-20
V	A G	6.7	25.6	122.5	9.3	0.95	20-40
VI	A G	7.1	45.0	121.5	12.5	1.09	20-40
CP	A UG	6.2	1.0	16.8	5.7	0.50	12 20

Sites: I. Corner of a sheep-grazed area, often used as resting place by sheep; thin soil layer; a place where extra feed has been supplied; richly dunged. - Södra Bårby. II. Dense grass tuft vegetation close to site I; samples taken where tufts provide high levels of organic matter. - Södra Bårby. III. Grazed area; not much dunged. - Karlevi. IV. Heavily grazed area close to a saltstone table and a resting place; richly dunged. Karlevi. V. Abandoned feeding place within a winter fold, now recolonized by different plants; heavily grazed area a few years earlier; dunged. - Karlevi. VI. Very heavily grazed area; frequently used as resting- and feeding place; richly dunged. Resmo. CP. Ungrazed area but harvested. Nedre Ålebäck.

Easily soluble P and K (P-AL and K-AL) are given in mg/100 g air dried soil, organic carbon (org.C), total nitrogen (tot.-N), and organic matter (OM) in percent.

Vegetation type: F = Festucetum, A = Avenetum, G = Grazed and UG = ungrazed.

Table 37. Proportions of produced dung and urine for cattle and sheep (kg year/animal) and contents of N, P, and K (kg/ton). - From Bengtsson & Kristiansson (1966).

	Produced amount	N	P	K
Cattle				
dung	8 500	5.0	1.1	2.1
urine	3 500	8.0	trace	11.6
Sheep				
dung	500	6.6	1.3	1.2
urine	100	16.0	trace	15.8

ungrazed *Festucetum* vegetation. Five or six samples were taken in the humus layer at each site (September 6—9, 1973). From each site a pooled sample was created from which two subsamples were analysed. Results of these analyses have been summarized in Table 36, including a description of the sites. Results from the soil analyses within the fertilization experiment are also given, and permit comparisons to be made despite the samples being taken in 1972 and the plots being harvested during 1970—72, nutrients thus being removed with the crop.

Analyses of manure for contents of N, P and K show that sheep manure is fairly rich in nitrogen and the urine has high contents of nitrogen and potassium (Table 37). These values show that large amounts of N and K are supplied by the animals to heavily grazed areas.

The grazed *Avenetum* and *Festucetum* areas investigated show high contents of these nutrients (see Table 36). In sites I and II (*Festucetum*) higher pH-values (7.6 and 7.3) were obtained than elsewhere on account of the weathered calcareous soil in which the vegetation is growing. At the other sites (*Avenetum*), the soil reaction is slightly acid, as this plant community is confined to till or littoral material. An exception is site VI (pH 7.1) where the soil layer is thin and probably influenced by the underlying limestone rock.

The decreasing pH-values with increased grazing found on an alvar area at Borgholm (Steen 1956 pp. 105 ff.) were not noticed in the present material. On the other hand, the increasing content of P-AL with higher grazing intensity (op. cit.) is found both for *Avenetum*- and *Festucetum*-vegetation. Sites II, III and CP are fairly equal, while sites that are heavily grazed, or influenced in other ways, show much higher values. The value for site VI is extremely high. These high contents of P-AL are obviously due to accumulated dung and urine as well as decomposed old litter from supplemental feeding (Steen op. cit.).

The trend for K-AL in the sites is largely the same as for P-AL. There are very high contents of K-AL in analyses from heavily grazed areas. The very high value of K-AL (135.0) obtained from site I is probably caused by local patches of urine and dung.

The organic carbon content also increased with higher grazing intensity, as dung and sometimes litter remnants from supplemental feeding had accumulated. Sites I and VI have extremely high values and in these sites droppings were frequent at the time of sampling. The fairly high value for site II may be referred to the high content of fine roots in the tufts.

The amount of total-N in the soil also increases with increased amounts of droppings. The value from site II is little higher than expected, but as humus and carbon content at this site were high, the value cannot be regarded as remarkably high. A positive correlation between low humus content and low amount of organic carbon occurs in sites III, IV and CP. Values from CP are the lowest in all respects, but are fairly close to those of ungrazed *Festucetum* (site II) and weakly grazed *Avenetum* (site III).

Comparing the other values from the fertilization experiment (Table 35), it is clear that only

plots supplied with the largest amount of fertilizer show higher values (in most cases) than the weakly grazed site III. Heavily grazed areas provide values much higher than the fertilized plots. The values of the fertilization experiment correspond fairly well to values obtained in cattle-grazed dry meadows at Kåtorp-Tävelsrum on Öland (Rodenborg 1976 pp. 40 ff.).

In an experiment in the Gorce Mountains, Poland, an area was influenced by sheep foldings and another not (Baradziej 1977 pp. 135 ff.). Fertilization resulting from folding increased the values of potassium and nitrogen considerably, carbon less and phosphorus only slightly; most pronounced in the uppermost part of the soil (0—3 cm). Seasonal variations were also found.

5 Standing crop and productivity during the grazing season 1972

5.1.1 Seasonal changes in plant cover composition

A special investigation was carried out in 1972 to get an impression of vegetation development during the main grazing season from May—October. It reflects the status from one month to another. A regular system of 88 plots of 25 x 25 cm, spaced at 10 cm intervals, was laid down in a homogeneous part of the *Avenetum*. Between every second row of plots a path was left to make is possible to harvest the plots without disturbing them by trampling.

Ten plots were sampled at random in early May, and then ten new ones each month until October. Dates when harvests took place are given in Fig. 16. The vegetation was cut off a few mm above the soil surface. The harvested material from all plots was separated into graminids, herbids, and dwarf shrubs; dead and living parts respectively at each harvest.

Living dwarf shrubs (*Helianthemum nummularium, H. oelandicum,* and *Thymus serpyllum*) were separated into current shoots and older parts. Within the group of living herbids, *Filipendula vulgaris, Oxytropis campestris, Plantago lanceolata, Potentilla* spp., and *Veronica spicata* were separated as they more or less dominated. The crop was dried at 80°C for 24 hours. The floristical composition of the *Avenetum* was similar to that of the fertilization experiment, located 50 m away.

The results for graminids, herbids, and dwarf shrubs, living and dead respectively, are presented month by month as mean values in Table 38. Values from additional separations of herbids and dwarf shrubs are found in Table 39.

Fig. 16 presents the distribution of dead, living and total standing crop during the season. For living and total standing crop (including necromass) two maxima were found, one in late June—early July and one in late August—early September. The reason for these two maxima may be the dry period that generally occurs in June—August (cf. 1.3.1 and Rosén 1980b p. 124).

The precipitation data shows that rainfall is irregular, sometimes only a few mm falling during long periods, which may then be followed by days with 20—30 mm. Precipitation values and mean maximum temperatures for the periods between the harvests are shown in Table 42.

As the first harvest was done in May there is no real zero value available for the start of the growing period. Further calculations must thus begin with the May value even if it is obvious that part of the early spring growth is not included.

A large part of the vegetation dies during the dry period. Some taxa are still photosynthetically active and also have some growth, although less than during conditions of more normal water supply.

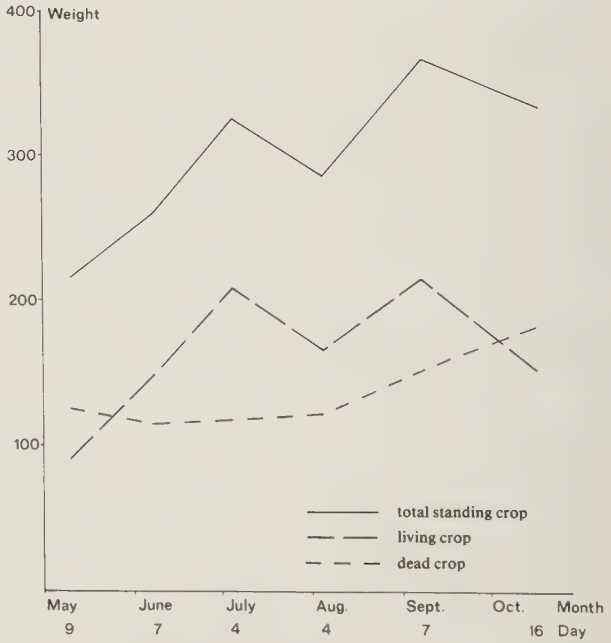


Fig. 16. Distribution of standing crop (g/m^2) in *Avenetum* vegetation in monthly harvests (May—October) in 1972. — Alvar of Nedre Ålebäck.

Table 38. Standing crops of components of monthly harvests in Avenetum vegetation, May–October 1972 (g/m²). (L = living, D = dead, G = graminids, H = herbids, DwS = dwarf shrubs, T.cr. = total standing crop) – Alvar of Nedre Ålebäck.

Month	Number of plots	LG	DG	LH	DH	LDwS	DDwS	Lcr.	Dcr.	Tcr.
M	9	36.6	54.2	25.4	56.2	27.8	14.4	89.9	125.0	214.9
J	10	48.8	50.1	53.1	44.6	45.8	19.2	147.5	113.8	261.3
J	10	65.4	52.2	75.8	37.6	66.4	27.0	207.7	116.8	324.5
A	10	55.7	55.2	62.2	46.7	47.2	18.4	165.1	120.5	285.6
S	10	77.9	73.8	56.8	40.5	80.5	37.4	215.2	151.7	366.9
O	8	66.6	79.8	41.3	65.5	43.7	35.7	151.5	181.1	332.6

Table 39. Standing crops of five selected dominant herbids and of dwarf shrubs (old and young parts) obtained by monthly harvests in Avenetum vegetation, May–October 1972. Values in g/m². Number of plots: (10) June–Sept., (9) May, and (8) October. – Alvar of Nedre Ålebäck.

Month	M	J	J	A	S	O
Filipendula vulgaris	4.3	14.6	14.1	9.4	8.0	6.2
Oxytropis campestris	2.6	6.6	15.0	6.7	5.1	9.3
Plantago lanceolata	1.4	4.0	4.2	3.7	3.4	5.0
Potentilla spp.	1.9	4.0	7.2	6.6	8.8	1.9
Veronica spicata	1.6	0.6	2.1	2.1	2.9	1.0
Living dwarf shrubs current-year shoots	19.4	34.4	52.5	36.2	61.3	28.3
old parts	8.5	11.4	13.9	11.0	19.2	15.4

Table 40. Monthly content of categories of plants (%) in Avenetum vegetation due to changes in standing crop during the investigation period May–October 1972. (D = dead, L = living, cr. = crop, G = graminids, H = herbids, DwS = dwarf shrubs) – Alvar of Nedre Ålebäck.

Month	Standing crop		Standing crop			Living crop		
	Dcr.	Lcr.	G	H	DwS	LG	LH	LDwS
M	58	42	42	38	20	41	28	31
J	44	56	38	37	25	33	36	31
J	36	64	36	35	29	32	37	32
A	42	58	39	38	23	34	38	29
S	41	59	41	27	32	36	26	37
O	54	46	44	32	24	44	27	29
Mean M–O	45	55	40	34	26	36	32	32

The drought period in 1972 was, however, not so serious as during other years and more taxa than usual were able to survive the period. This enables them to start a considerable production in August—September when rain fell again, giving a maximum for the living crop that was even higher than in June—July. Dead standing crop clearly increased in connection with the drought period.

The separation into components make it possible to trace differences during the season between herbids on one hand and graminids and dwarf shrubs on the other (Fig. 17). Herbids give the highest value of standing crop in July. Then they decrease continuously towards the autumn. During June—August, herbids show the highest percentage values in the living crop (36, 37 and 38) in comparison with graminids and dwarf shrubs (Table 40). The main floral time for most of the herbids occurs in June—July.

Graminids and dwarf shrubs show maxima in late June—early July and in late August—early September. The latter period is most prominent due to favourable productivity conditions that year. Both curves reach almost the same maximum values, but graminids start with higher values in May and the difference appears even more prominent in October.

Current shoots of dwarf shrubs show the same trend as values for living dwarf shrubs totally, but of course with lower values as ligneous parts have just developed in the current shoots. An explanation of the more rapid decrease in standing crop for dwarf shrubs compared with graminids in September—October ought to be their loss of fertile parts, e.g., fruits with seeds and also parts of stems and some leaves.

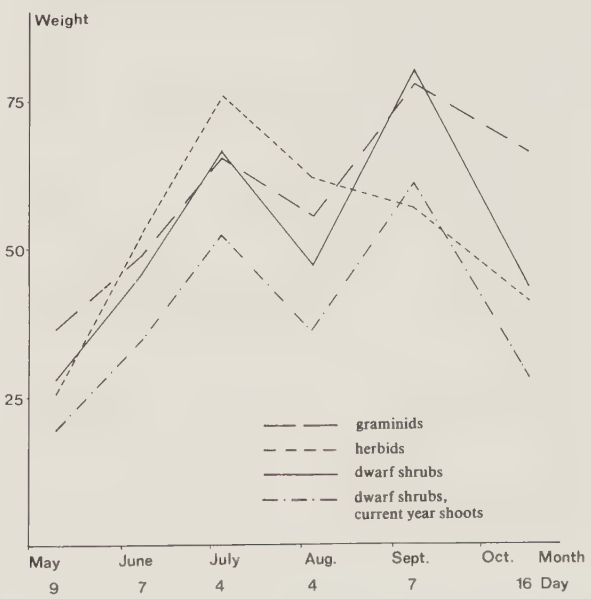


Fig. 17. Distribution of living crop (g/m²) in *Avenetum* vegetation in monthly harvests (May—October) in 1972. — Alvar of Nedre Ålebäck.

Graminids grow vegetatively until snow or frost stop their further growth. In some exceptional years without snow and with temperatures above 0°C, parts of the vegetation remain green and show a small growth even in winter. The winter of 1971—72 had some periods of snow and a temperature fluctuation around 0°C. No growth could be expected from December to mid-March. However, numerous plants survive the winter with green leaves.

Steen (1957) investigated the seasonal botanical variation in two natural pasture swards in Lövsta and Åsbo (province of Uppland), as regards cover and occurrence of all taxa on six occasions from May—December 1955. Although his values originate from other types of vegetation than on the Alvar, the comparison may be useful.

He found that somewhat more than half the number of all recorded taxa hibernate with green parts, but with reduced amounts. There was a change in composition during winter in the plant cover. About 25% of all taxa recorded in December were not found in May, but this loss had been almost counterbalanced by the arrival of other taxa. There was a strong reduction of aboveground biomass during the winter (op. cit. pp. 20 ff.). Most probably, figures similar to these could be obtained from the *Avenetum* vegetation of the Alvar.

Herbids are most sensitive to climatic changes during the season, and also have a more pronounced biological rhythm than graminids. Graminids are more frequent in the late and early parts of the season and probably hibernate with green parts to a larger extent than herbids (op. cit. p. 21). As graminids in the present investigation show high values within the living crop in May and in October, they may also have the largest frequency on the Alvar of hibernating green parts.

The variation in standing crop for different components of the vegetation is shown in Table 40 to provide a more detailed complement to the curves. During the main grazing season, an average of 45% of the standing crop was dead material. Standing crop values for living crop were higher from June to September. Similar trends and proportions for living crop during the grazing season were shown from a sheep pasture in Poland (Andezejewska 1974, p. 529).

Among living plants the values for the season were, on average, 36% for graminids, 32% for herbids, and 32% for dwarf shrubs (perennial ligneous parts being included in the value for dwarf shrubs). The separation of the total standing crop into these components gave 40%, 34% and 26%, respectively.

These figures can be compared with those of the control plots in the fertilization experiment (if lost biomass is assumed to be of the same amount), where the values were 54%, 26%, and 20%. Another comparison with values from permanent plots, harvested for the first time in 1972, gave 61%, 28%, and 11% respectively. All these figures indicate that in an ungrazed *Avenetum* area there is a higher percentage of graminids than herbids, and herbids have a higher percentage than dwarf shrubs.

The value of 40% for graminids is low, being a mean value for the season, while the other values are represented only by the situations in August and in November. The October values of the season investigation are 44%, 32%, and 24%, respectively, and may be more adequate for purposes of comparison.

Results obtained by extractions of five dominant taxa of the living herbids are shown in Fig. 18. The range of variation for each of these five taxa is naturally wider than for a group of taxa, and thus these values become more unreliable than for a group. The distribution of a single taxon is generally irregular within small areas. The harvested number of specimens of a certain taxon thus varies between the plots and so does the size reached by

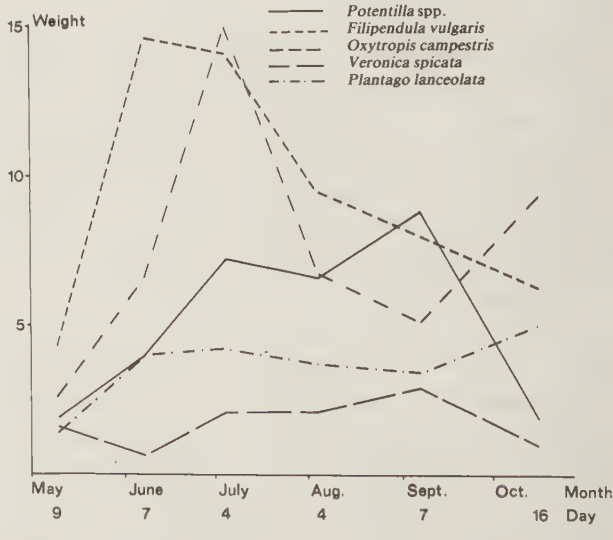


Fig. 18. Distribution of living crop (g/m^2) for five herbids in *Avenetum* vegetation selected from monthly harvests (May—October) in 1972. — Alvar of Nedre Ålebäck.

each harvested specimen. The total harvested amount of one taxon is also smaller than for a whole group of herbids, and thus more subjected to irregularities in distribution patterns. In spite of these expected variations in the material, curves of the five taxa have been presented as they illustrate some trends observed in the development of the vegetation in the field. *Filipendula vulgaris* and *Oxytropis campestris* have their main floration period in June—July and are usually very frequent around midsummer. These conditions appear in Fig. 18 as pronounced maxima. *Veronica spicata* flowers in July—August or even later. *Potentilla* spp., and *Plantago lanceolata* are more evenly distributed during the season.

In Table 41 a comparison may be made between the five selected taxa and their percentage amounts during the season in living herbids and in living crop. *Filipendula vulgaris* is the most dominant of the five taxa almost throughout the whole season, with the highest value (27%) of living herbids in June. *Oxytropis campestris* represents 20% in July and 23% in October. Compared with the total living crop, these five taxa represent a very small part, except for *Filipendula* which reached 10% in June.

A comparison with investigations of similar *Avenetum* vegetation (Ammar 1978) on beach ridges on Öland might be useful. His sites on the Ancylus ridge are the most interesting ones for comparison, although situated on much deeper littoral material than on the Alvar.

Ammar's investigations were made in almost the same way as the present ones, comprising harvests each month during May—October, and separations into various components. His material (1978 p. 89, Table 12) also shows two maxima for living plants during the season. In 1975, values for living plants decrease continuously from a high level in May, through a very dry summer to a new production period in autumn. In 1976 and 1977, which had more normal precipitation conditions, the largest part of the living plant fraction was found during the summer. After a decrease, there is a small increase in late autumn.

Table 41. Five selected taxa in percentage of living herbids (A) and of living crop (B) in Avenetum vegetation, monthly during May-October 1972. - Alvar of Nedre Alebäck.

Month	M	J	J	A	S	O
A						
Filipendula vulgaris	17	27	19	15	14	15
Oxytropis campestris	10	12	20	11	9	23
Plantago lanceolata	6	8	6	6	6	12
Potentilla spp.	8	8	10	11	16	5
Veronica spicata	6	1	3	3	5	2
B						
Filipendula vulgaris	5	10	7	6	4	4
Oxytropis campestris	3	5	7	4	2	6
Plantago lanceolata	2	3	2	2	2	3
Potentilla spp.	2	3	4	4	4	1
Veronica spicata	2	0.4	1	1	1	1

Ammar's graminaceous plants (graminids) have a smaller part of the living standing crop than the herbaceous plants (herbids), but it must be borne in mind that Ammar included dwarf shrubs in the latter group. If they had been treated separately a composition more similar to that of the present investigation would have been obtained. His herbaceous plant group was dominant during summer, and its increase during autumn was probably the result of dwarf shrubs being included.

As my investigation was not carried out during the same year, and consequently under different conditions, any conclusions reached as the result of a comparison should be treated with caution.

5.1.2 Standing crop and production

Estimates of standing crop and productivity can be obtained in several ways from standing crop values at the harvested plots. Tables 38 and 39 present standing crop values for total above-ground biomass and for various components at six dates during the main grazing season (May—October). Harvest dates are given in Fig. 16.

A production value for living crop during May—October is obtained by adding the positive differences from one harvest to the next (cf. Table 38, Fig. 16), thus: $(X_{June}-X_{May}) + (X_{July}-X_{June}) + (X_{Sept.}-X_{Aug.})$, giving a value of 168 g/m^2 dry weight (1680 kg/ha). The value is considered to be too low since (1) some newly produced material may have been blown away or dropped, (2) consumption by insects is not taken into account, and (3) production in periods with a negative crop increase is not included.

A production value for seasonal total standing crop is obtained by the addition of positive differences for the total standing crop. This results in a value of 191 g/m^2 (1910 kg/ha), which is also too low. A more realistic approach is to sum the values for total standing crop in August and the increase of living crop from August to September, which gives 336 g/m^2. This value corresponds well with the total value of 344 g/m^2 obtained at the end of the season in the (permanent) enclosure plots, although the latter reflect slightly different periods (cf. 3.2.1).

The estimate of 336 g/m^2 is again too high since dead and even some living material from the year

before is included. On the other hand, production values from the periods July 4—August 4, and September 7—October 16 are lacking.

Various procedures have been suggested (e.g. Wiegert & Evans 1964) to account for losses of biomass by wind, decomposition and unmeasurable production in periods of negative net crop increase. These were not applied because of the uncertainties involved, especially concerning biomass loss.

Another approach is based on relations between short-term primary productivity and weather conditions such as precipitation, actual evapotranspiration and mean annual temperature (cf. Lauenroth 1979; Sims & Coupland 1979). Some results are presented in Table 42. Productivity per day is calculated from differences in standing crop from month to month. No trend is seen, except for the relation between the low value of precipitation and fairly high temperature in the interval June—July, and the decrease in standing crop over July—August shown in Fig. 16. There is evidence that vegetation responds to fluctuations in rainfall especially in habitats with low precipitation, such as the Alvar (cf. the long-term recordings of cover degrees in the permanent plots, 3.2.2).

Experimental evidence has been presented by van der Maarel (1981) for a dry dune grassland in the Netherlands and by Detling (1979) on the dominant grass *Bouteloua gracilis* in the short grass prairie in Colorado. The general suggestion is that water is a major limiting factor in grassland production. A similar response may be expected in the Alvar.

Combining increases of current shoots and older parts of dwarf shrubs as well as increases for single taxa of important herbids in August—October (Fig. 18), with the increases of living graminids and living herbids, values of productivity per day were obtained for monthly intervals (Table 43).

Concerning periods of decreasing standing crop, the productivity in July—August is supposed to be at least half of that in June—July (for all groups), due to the previous drought period. As herbids show a continuous decrease from a maximum in late June—early July, only values obtained from single taxa are included for August—October (cf. Figs. 17 and 18).

Graminids and dwarf shrubs show a second maximum of standing crop in late August—early September. Their September—October values are assumed to be half of those in August—September. Estimated values are shown in Table 43.

Table 42. Productivity ($g/m^2/day$) in Avenetum vegetation compared with mean maximum temperatures (°C) and precipitation (mm) in the intervals between monthly harvests during May-October 1972 (160 days). - Alvar of Nedre Ålebäck.

Period	April-May	May-June	June-July	July-Aug.	Aug.-Sept.	Sept.-Oct.
Number of days	30	29	27	31	34	39
Mean max. temp.	11.4	16.5	20.7	23.9	19.7	14.0
Precipitation	16	41	13	59	65	62
Precip./day	0.5	1.4	0.5	1.9	1.9	1.6
Prod./day	(--)	2	2.2	-1.4	1.5	-1.6

Table 43. Productivity per day (g/m^2) for components of Avenetum vegetation in periods during May-October 1972. (160 days). Values within brackets are calculated from single taxa. Estimated values are underlined. (LG = living graminids, LH = living herbids, LDwS(y) = living dwarf shrubs, current-year shoots, LDwS(o) = living dwarf shrubs old parts). - Alvar of Nedre Ålebäck.

Period	May June	June-July	July Aug.	Aug.-Sept.	Sept.-Oct.
Days	29	27	31	34	39
LG	0.4	0.6	0.3	0.7	0.4
LH	1.0	0.8	0.4	(0.1)	(0.2)
LDwS(y)	0.5	0.7	0.3	0.7	0.3
LDwS(o)	0.1	0.1	0.1	0.2	0.1
Totally	2.0	2.2	1.1	1.7	1.0

For productivity, within monthly intervals, the August—September productivity value obtained is lower than for June—July, because of the low productivity by herbids. On the basis of these figures, the production for the investigated period (May—October) can be estimated as 248 g/m^2 (2480 kg /ha).

The investigation has shown pronounced variations in standing crop and productivity during parts of the investigated period, for groups of plants or single taxa, and for living versus dead biomass. A period of drought is reflected in a decreasing amount of living crop. Although referring only to 1972, the figures may be considered appropriate in a general planning of the stocking rate on the Alvar.

A decrease of standing crop as well as living crop during a certain part of the grazing season may cause a lack of herbage for the animals, even if the total production value for the season suggests that a sufficient amount is available. Consequently, the number of animals should be reduced during and after a drought period, or the animals should be supplied with extra herbage, otherwise the area will become overgrazed (cf. 7.1.4 on selectivity).

6 Natural and experimental changes in Avenetum vegetation with junipers

The structure of the Alvar vegetation is closely related to activities by man. When the grazing pattern in an area changes it also results in changes in the vegetation. In some areas the composition of the number of grazing animals changed during this century to become dominated by sheep, followed within a few years by a decrease of shrub vegetation. In some heavily grazed areas almost all shrubs were killed (cf. 7.1.2). In contrast, there were also areas subject to a decrease in grazing intensity, now extensively grazed by cattle or by a small number of sheep. In such areas with deep soil an invasion by *Juniperus communis* will take place, forming a more or less dense scrub, often with *Prunus spinosa* and *Rosa* spp., and also with *Betula verrucosa* and *Sorbus intermedia*. Large areas have thus been invaded over the last 50 years or so, as the number of animals has not been sufficient to eliminate all seedlings of these shrubs and trees.

As little was known about the kind and rate of ecological changes taking place due to such an invasion, an experiment was carried out in an area with a high frequency of junipers. For the future management of the Alvar it was considered important to trace the results of a clearing of an area, as well as the total protection from grazing animals by an enclosure.

6.1 Permanent plots with junipers

An area with a rich variation in age and shape within a *Juniperus communis* stand was chosen in the Alvar of Nedre Ålebäck. Two large permanent plots, each 50 x 50 m, were delimited and fenced. In the test plot all junipers were mapped in 1970, and those in the control plot in 1971. Their height and diameter (in two directions) were measured, excluding the smallest shrubs and seedlings. The junipers were separated into four main classes on the basis of their longest diameter: I (0—1 m), II (1.05—2 m), III (2.05—3 m) and IV (> 3.05 m). Later a class 0 was added for the small shrubs and seedlings that were only measured in some respects.

Totally 201 junipers were found in the test plot. Of these 102 were classified into classes I—IV. A sample of 23 junipers (about 20%) was chosen at random from these 102 shrubs, being representative for the stand in the dry matter estimation. The two plots were photographed from all sides, and the 23 selected shrubs were photographed separately.

6.1.1 Standing crop in the test plot

When documentation had been completed all junipers in the plot were cut down in the autumn 1970. The classified shrubs (102) and 34 smaller ones were weighed separately, and a segment of each was removed for age-determination. The remaining 65 very small junipers were weighed together.

The 23 sampled shrubs were kept at room temperature for about 6 months to obtain a dry weight of the stand. When they were dry, assimilating parts (needles and year-shoots) of each shrub were separated from the wooden parts and weighed separately. Results from age-determinations are presented in Figs. 19 and 20. The individual shrubs (Fig. 19) had ages evenly spread from 20 up to 87 years. Only the ages of 33 and 44 are slightly more frequent than the others. The oldest shrub was 116 years old (shrub no. 32, height 0.6 m, fresh weight 16.3 kg, and with the diameters 2.95 and 3.10 m) and the youngest one 14 years. It must be remembered that 65 very young junipers did not get their ages determined, and might be in the interval from 1 to 15 (20?) years.

For the counted junipers (136) the mean age is 49 years. There seems to be a decrease in frequency from about 70 years and older. A higher grazing intensity, as well as cutting for firewood around 1900 and earlier, could be a reason but a combina-

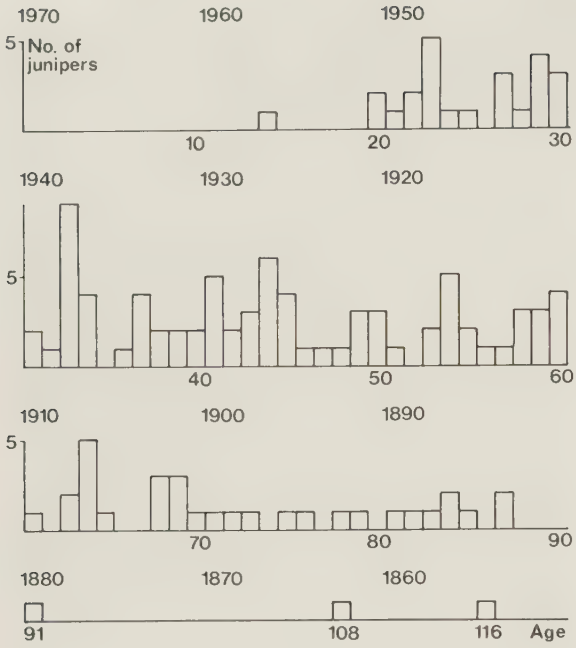


Fig. 19. Age-distribution of 136 junipers from the cleared test plot in 1970. Mean age 49 years. — Alvar of Nedre Ålebäck.

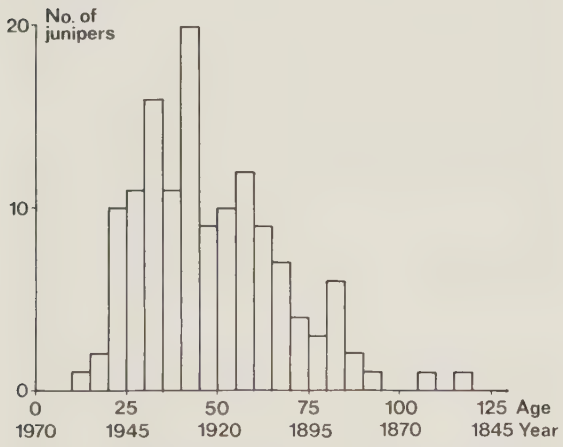


Fig. 20. Age class distribution (5 years intervals) of 136 junipers from the cleared test plot in 1970. Mean age 49 years. — Alvar of Nedre Ålebäck.

tion with extreme drought periods, killing shrubs, cannot be excluded. In Fig. 20 (classes with 5-year intervals), a peak is seen for ages 41—45 years and a less pronounced one for 31—35 years. These peaks may correspond to periods of decreased grazing intensity and thus better facilities for seedlings to establish and survive. Comparing the number of animals at Gårdby (7.1.1, Fig. 27), there is a pronounced decrease for sheep, horses and oxen 35—40 years ago, which may be connected with the age distribution above.

Table 44. Number of junipers (201) in the test plot (50 x 50 m) in 1970, distributed in diameter classes (see text). Mean age (year), mean height (cm), mean fresh weight (kg) and total weight are given. Total fresh weight of the stand: 1275 kg. (In calculations of mean weight and height, one shrub from class 0 was temporarily included in class I.) - Alvar of Nedre Ålebäck.

Class	0	I	II	III	IV
No. of shrubs	65	34	20	36	29	17
Mean fresh weight	0.05	0.42	1.53	5.33	13.42	37.94
Mean age	-	31	42	50	59	73
Mean height	-	-	0.53	0.68	0.77	1.0
Total fresh weight	3	14	32	192	389	645

Table 45. Representative sample of 23 junipers from the test plot. Mean values of age, height (cm), fresh weight (kg), dry weight, water loss (%), and proportion of needles/wood (%). Number of junipers within brackets. - Alvar of Nedre Ålebäck.

Class	Age	Height	Fresh wt.	Dry wt.	Water l.	Needl.	Wood
I (5)	51	0.7	2.38	1.44	40	50	50
II (8)	47	0.63	6.09	3.83	37	45	55
III (5)	56	0.7	14.74	9.44	36	47	53
IV (4)	78	1.05	55.53	35.68	36	35	65

When considering the 65 very young shrubs mentioned above, they should have created some very high maxima in the younger classes in Fig. 20 if they had been counted. However, they show a strong colonization in the stand, causing the mean age to decrease continuously.

The fresh weight of the stand (standing crop) in the test plot was 1275 kg, or 5100 kg per hectare (Table 44). The weights of class 0 and class I represent a very small part of the total weight. Class IV itself reaches a value 15 kg higher than all the others together. The higher the class the higher the values obtained for mean weight, mean age, and mean height.

The dry weight for the stand is obtained from calculations on values from the representative shrubs (sample of 23 shrubs) dried at room temperature (Table 45). Mean values for age, height, and fresh weight correspond fairly well to those obtained from the total stand (Table 44), except for class I where the sample shows higher values than for the stand, and for class IV as regards fresh weight.

The four classes show different losses of water, probably due to the different shares of assimilating and wooden parts in the various classes. In class I the proportions are 50 to 50% but in higher classes

with older and bigger shrubs 65% is represented by wood (IV). The loss of water from needles is higher than from wood and thus younger shrubs lose somewhat more water than old ones in relation to their total weight. If the fresh weight is reduced class by class with these proportions, and the small shrubs are included into class I, 812 kg is obtained for the total stand, which gives 3248 kg dry weight/ha.

The weight of assimilating parts amounts to 1323 kg/ha, if calculated upon percentages characteristic to each class. For the total stand, the loss of water is 36% and the shares of assimilating and wooden parts are 41% to 59%.

6.1.2 Colonization of needle-covered areas

A thick layer of dry needles was found under most of the cut junipers. To follow the supposed succession towards dry meadow vegetation the colonization of the needle areas for the representative 23 shrubs (20%) has been recorded from 1971 to 1977.

These areas are different in size, shape and thickness of the needle cover. There were very few phanerogams, especially on areas with thick needle cover. In other areas there was a dense moss cover mostly in the northern part formerly shaded by the shrub. Mosses were also distributed over the area if the cut shrub had been low and loose. Such shrubs permit some rain and light to penetrate, creating possibilities for growth, which could be very limited on a dry needle cover in a dark shrub. The dominating mosses were *Hylocomium splendens* and *Rhytidiadelphus triquetrus*.

In the autumn of 1971 (the year after the cutting) very little had happened within the areas. In some areas a scattered colonization could be seen. However, in the two following years there were more frequent changes. Almost all mosses disappeared from the needle areas, probably as a result of increased exposure and drought. *Hylocomium* seemed to be the less drought tolerant species. Only a few patches of the former moss cover survived among other plants close to the borders of the areas, but rarely separated from the borders.

A remarkable colonization took place in 1972 and 1973 by tall and easily spreading taxa such as *Filipendula vulgaris, Fragaria viridis, Artemisia laciniata, Galium boreale, Cirsium acaule, Arrhenatherum pratense, Poa compressa*, and *Phleum phleoides*, but also locally by *Carex flacca, Poa angustifolia* and close to the borders by *Briza media*. Also some annual species appeared (Plate 3:1—4).

In 1974 some of the areas had recovered fairly well while others still had very large open surfaces. Numerous shoots of *Prunus spinosa* and *Rosa* spp. appeared. The colonization continued and from that year the above-mentioned taxa became more dominant and competed with an increased amount of other taxa appearing more irregularly, such as annuals.

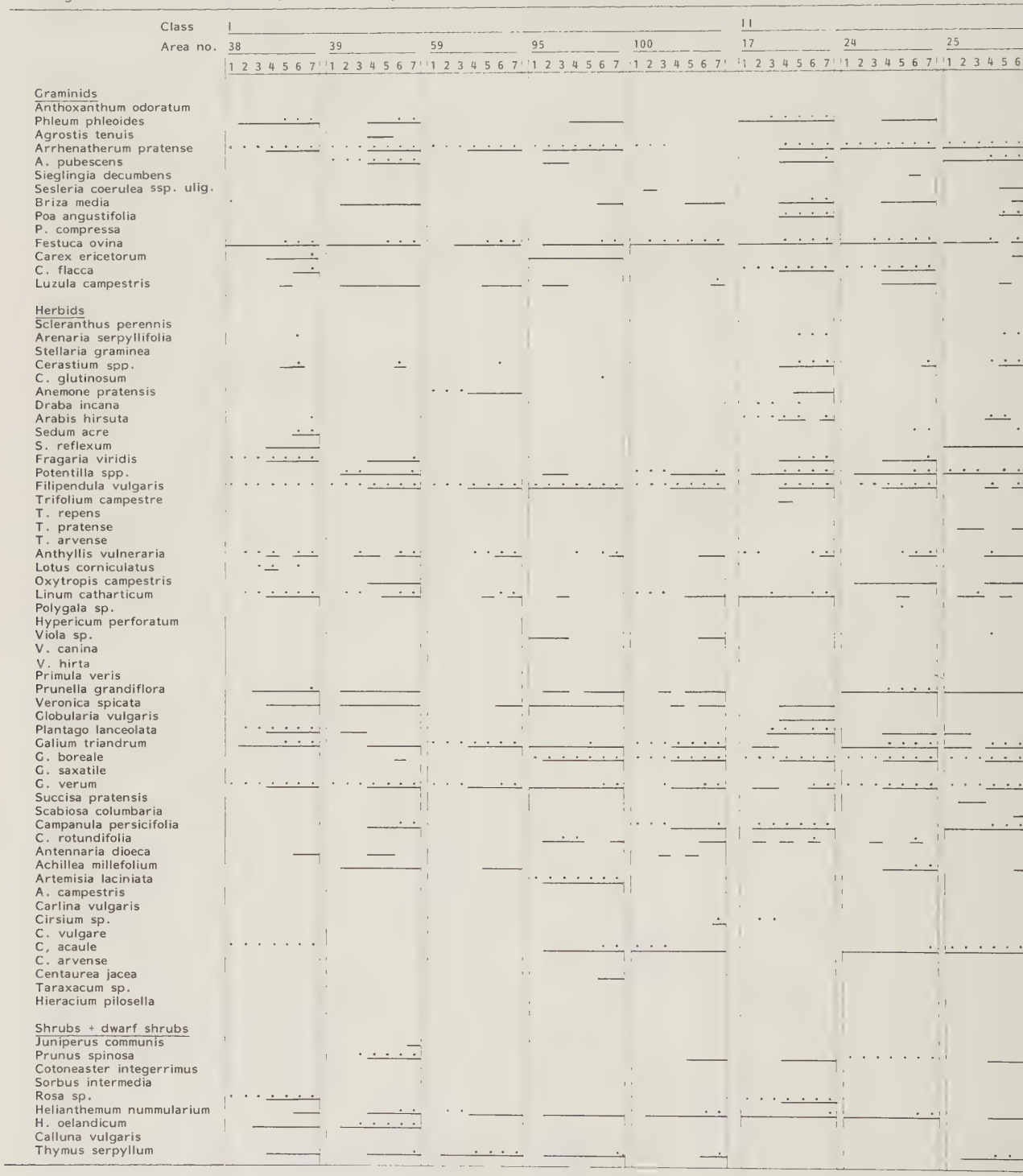
In 1975, 7—10 areas were almost totally covered by vegetation, leaving very small patches of bare soil for colonization. There were still large open surfaces in the other areas. No certain size of area was colonized faster than the other ones. In 1977 still 10 of the 23 areas were not completely covered. During the full period of 5—7 years all areas became colonized to 75% or more. In 1981 only three areas still had small open patches of soil.

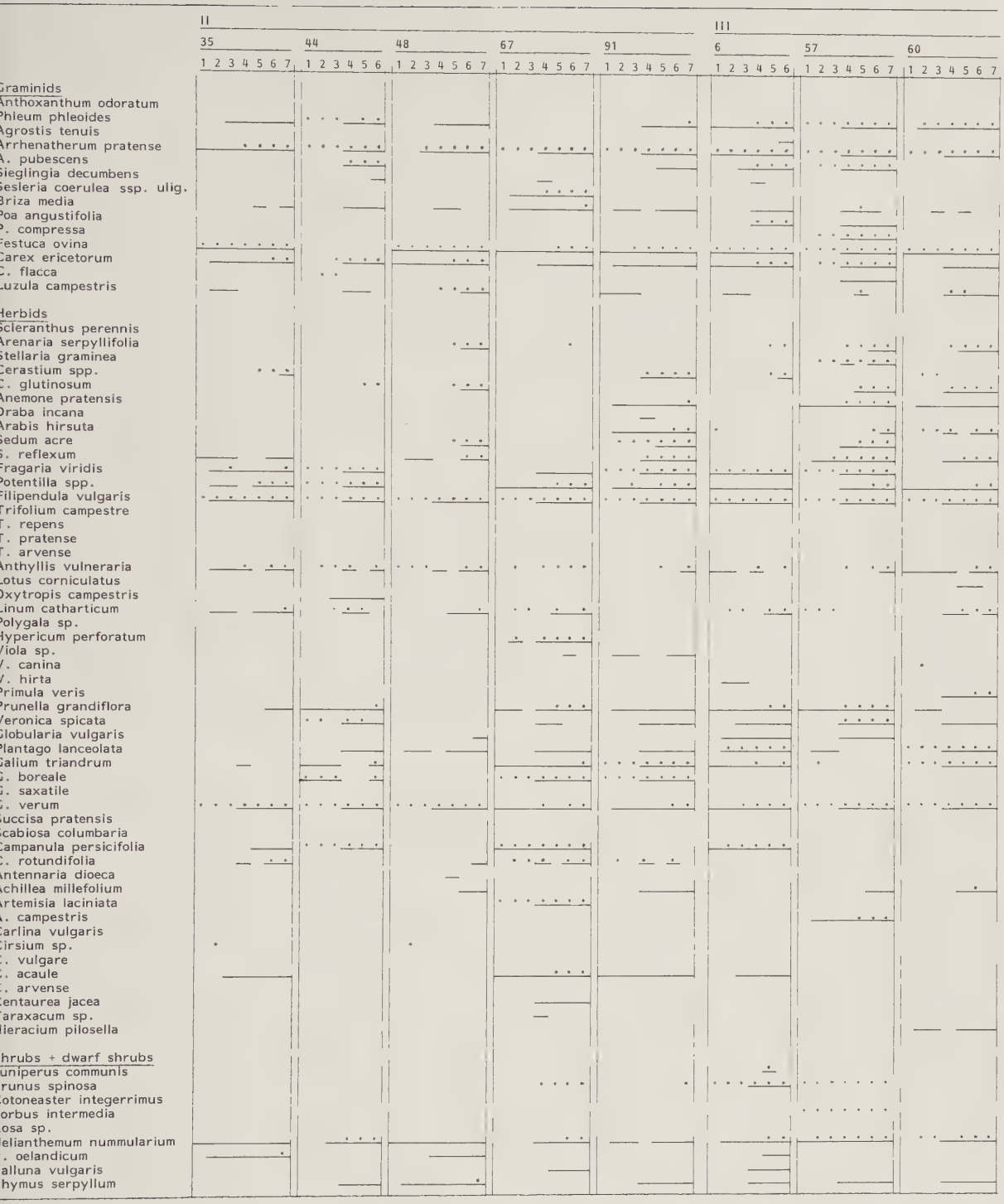
The colonization took place in different ways, both from the borders and from former vegetation patches within the areas, and also as spots of new colonization. As these patches spread in different directions, the open patches, subjected to damage by rain or wind erosion or even frost-induced soil movements, became smaller and smaller.

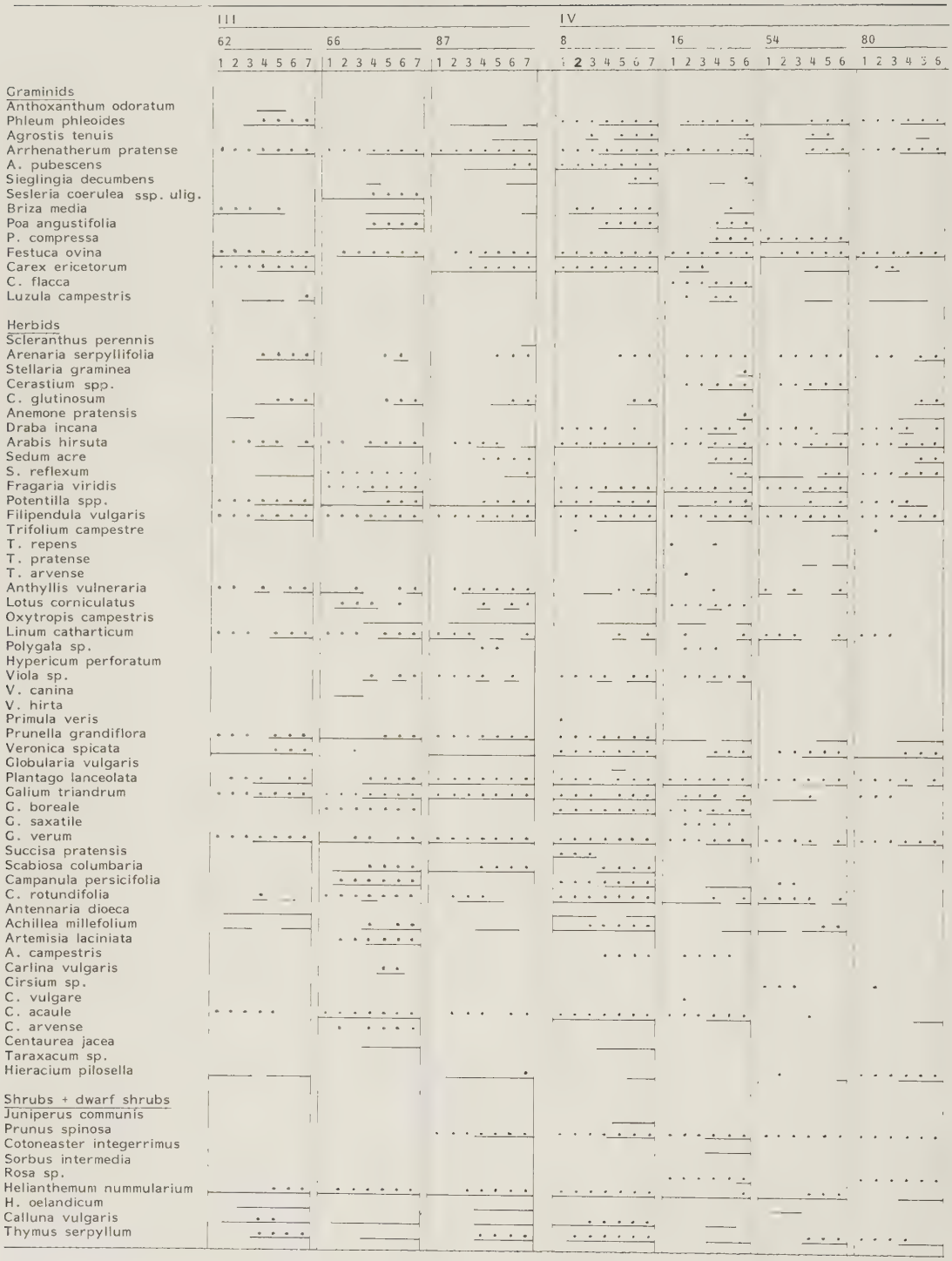
More detailed information on the colonization is given in Table 46, the data having been compiled during August/September as a registration of occurrence. Each taxa has been recorded as to its occurrence in the open area or in the colonizing front, about 10 cm from the border, or in both positions. Thus it is seen whether a certain taxa occurred in the central part or not. Generally it can be seen in Table 46 that the larger the size of an area (diameter class), the more taxa are involved, which was expected. There were also more taxa involved in the first steps of colonization in the larger than in the smaller areas.

Arrhenatherum pratense, Filipendula vulgaris, and *Galium verum* seem to have the most regular occurrence from the start of the colonization. In some cases they may have been within the areas from the beginning, as they were found within living juniper shrubs.

Table 46. Records of phanerogams colonizing needle areas during 1971-77, where junipers had been cut. 23 areas of various size was inventoried. Thi
was done as a registration of occurrence showing the establishment of certain taxa in the bare needle area (• • • • •) or within the colonizing front
extending about 10 cm from the border (———). Test plot with junipers. - Alvar of Nedre Alebäck.




II
III
35
44
48
67
91
6
57
60
1 2 3 4 5 6 7
1 2 3 4 5 6
Graminids
Anthoxanthum odoratum
Phleum phleoides
Agrostis tenuis
Arrhenatherum pratense
A. pubescens
Sieglingia decumbens
Gesleria coerulea ssp. uliginosa
Briza media
Poa angustifolia
P. compressa
Festuca ovina
Carex ericetorum
C. flacca
Luzula campestris
Herbids
Scleranthus perennis
Arenaria serpyllifolia
Stellaria graminea
Cerastium spp.
C. glutinosum
Anemone pratensis
Draba incana
Arabis hirsuta
Sedum acre
S. reflexum
Fragaria viridis
Potentilla spp.
Filipendula vulgaris
Trifolium campestre
T. repens
T. pratense
T. arvense
Anthyllis vulneraria
Lotus corniculatus
Oxytropis campestris
Linum catharticum
Polygala sp.
Hypericum perforatum
Viola sp.
V. canina
V. hirta
Primula veris
Prunella grandiflora
Veronica spicata
Globularia vulgaris
Plantago lanceolata
Galium triandrum
G. boreale
G. saxatile
G. verum
Succisa pratensis
Scabiosa columbaria
Campanula persicifolia
C. rotundifolia
Antennaria dioeca
Achillea millefolium
Artemisia laciniata
A. campestris
Carlina vulgaris
Cirsium sp.
C. vulgare
C. acaule
C. arvense
Centaurea jacea
Taraxacum sp.
Hieracium pilosella
Shrubs + dwarf shrubs
Juniperus communis
Prunus spinosa
Cotoneaster integerrimus
Sorbus intermedia
Rosa sp.
Helianthemum nummularium
H. oelandicum
Calluna vulgaris
Thymus serpyllum


III
IV
62
66
87
8
16
54
80
1 2 3 4 5 6 7
Graminids
Anthoxanthum odoratum
Phleum phleoides
Agrostis tenuis
Arrhenatherum pratense
A. pubescens
Sieglingia decumbens
Sesleria coerulea ssp. ulig.
Briza media
Poa angustifolia
P. compressa
Festuca ovina
Carex ericetorum
C. flacca
Luzula campestris
Herbids
Scleranthus perennis
Arenaria serpyllifolia
Stellaria graminea
Cerastium spp.
C. glutinosum
Anemone pratensis
Draba incana
Arabis hirsuta
Sedum acre
S. reflexum
Fragaria viridis
Potentilla spp.
Filipendula vulgaris
Trifolium campestre
T. repens
T. pratense
T. arvense
Anthyllis vulneraria
Lotus corniculatus
Oxytropis campestris
Linum catharticum
Polygala sp.
Hypericum perforatum
Viola sp.
V. canina
V. hirta
Primula veris
Prunella grandiflora
Veronica spicata
Globularia vulgaris
Plantago lanceolata
Galium triandrum
G. boreale
G. saxatile
G. verum
Succisa pratensis
Scabiosa columbaria
Campanula persicifolia
C. rotundifolia
Antennaria dioeca
Achillea millefolium
Artemisia laciniata
A. campestris
Carlina vulgaris
Cirsium sp.
C. vulgare
C. acaule
C. arvense
Centaurea jacea
Taraxacum sp.
Hieracium pilosella
Shrubs + dwarf shrubs
Juniperus communis
Prunus spinosa
Cotoneaster integerrimus
Sorbus intermedia
Rosa sp.
Helianthemum nummularium
H. oelandicum
Calluna vulgaris
Thymus serpyllum

For comparison, *Filipendula vulgaris* followed by *Galium verum* was reported to survive for a long time under a canopy of *Calluna vulgaris* in an English heathland (Grubb et al. 1969 pp. 190 ff.).

Slightly later, and fairly regularly, the following species are found: *Festuca ovina, Potentilla* spp., *Phleum phleoides, Fragaria viridis, Plantago lanceolata,* and *Galium triandrum.* Occurring frequently but irregularly are: *Arenaria serpyllifolia, Cerastium* spp. (most specimens belong to *C. glutinosum*), *Arabis hirsuta, Linum catharticum,* and *Anthyllis vulneraria.* Variations in occurrence due to climatic variations may be traced. *Anthyllis,* e.g., was less frequent in 1975, probably due to low precipitation that year (cf. 1.3.1).

Frequent invaders from the borders were *Oxytropis campestris, Prunella grandiflora, Veronica spicata, Helianthemum nummularium,* and *Thymus serpyllum.* In most of the areas a pronounced increase in the number of taxa took place during the last 3—4 years of the investigated period.

These recordings show clearly that natural colonization of areas where junipers have been cut down is slow, implying a large risk for the start of erosion in needle-covered areas if heavy grazing starts too soon following the clearing. Grazing intensity ought to be increased step by step during the first five years.

6.1.3 Acidification by junipers

Initial pH-values from *Juniperus* needle areas were measured in order to trace possible changes due to the colonization of vascular plants and to the interruption of the supply of acid needles to the soil after the clearing. Five of the former selected areas were chosen at random, one for each class. From the central part of an area (close to the stem) soil samples were taken at distances of 50 cm towards the border of the needle area and about 100 cm outside the former shrub. The samples were also taken at 5 cm intervals from the surface of the soil and as deep as possible until the rock stopped the core sampler. These samples were taken and analysed once a year from 1970 to 1972 (October/November) south- and northwards from the centre of the five junipers.

The samples from 1971 were taken 10—15 cm on one side of those taken in 1970, and those from 1972 were taken on the other side. The pH-values were measured in H_2O as well as in 0.2 M KCl-solution.

Table 47. Distribution of pH-values within soil samples taken in October and/or November 1970-72, from a needle area of a cut juniper (No. 67, class II, age 45 years). Samples were taken from various depths (5 cm intervals) and in two directions from the centre (50 cm intervals). (N = north, S = south, dotted line = border of the area.) - Alvar of Nedre Alebäck.

	pH-KCl			pH-H_2O		
Year	1970	1971	1972	1970	1971	1972
N I	6.5	6.8	6.2	7.3	7.4	6.9
	6.0	6.5	6.1	7.0	7.3	6.9
	6.0	6.5	6.2	7.0	7.3	7.1
	6.3			6.3		
N II	6.5	6.9	6.7	7.2	7.5	7.3
	6.3	6.6	6.4	7.2	7.3	7.1
	6.3	6.3	6.5	7.2	7.2	7.3
		6.7	6.8		7.4	7.5
N III	6.4	6.1	5.6	7.1	6.8	6.5
	6.3	5.8	5.7	7.1	6.7	6.7
	6.3	5.9	5.8	7.1	6.8	6.8
	6.7		6.0	7.4		7.1
N IV	6.4	6.8	6.2	7.0	7.5	6.9
	5.7	6.5	5.9	6.7	7.2	6.8
	5.7	6.2	5.8	6.8	7.0	6.9
	6.4	6.3	6.4	7.2	7.1	7.1
S I	6.9	6.9	6.7	7.5	7.7	7.2
	6.3	6.7	6.4	7.3	7.6	7.2
	6.1	6.6	6.1	7.3	7.6	7.2
	6.7	6.8	6.3	7.4	7.8	7.3
S II	6.9	7.0	6.8	7.4	7.6	7.4
	6.2	6.5	6.5	7.1	7.3	7.3
	6.4	6.3	6.4	7.2	7.0	7.4
		6.4			7.2	
S III	6.9	6.4	6.7	7.4	7.1	7.2
	6.4	6.1	6.3	7.2	6.8	6.9
	6.0	6.0	6.2	7.1	6.7	7.1
	6.2	5.9	6.6	7.1	6.8	7.3
		6.1			7.0	
		6.3			7.2	
S IV	6.4	6.8	6.8	7.0	7.4	7.3
	6.4	6.6	6.0	7.1	7.4	6.9
	6.1	6.5	5.9	7.1	7.4	7.0
	6.0	6.7	6.1	7.0	7.5	7.2
	6.1			7.2		
	6.4			7.3		
	6.8			7.5		

Values obtained for the three years ranged within pH 4.0—7.0 (KCl) and pH 5.5—7.8 (H_2O). In 1971 the values were generally higher than in 1970. In contrast, the 1972 values were lower than in 1971, although the pattern was somewhat irregular.

The lowest pH-values were frequently found at the border of the needle area, where the former edge of the juniper had been. However, single exceptionally low values were found centrally in the needle areas of the two oldest junipers (83, 85 years) in the sample. The distribution of pH-values is exemplified from one area in Table 47.

A large amount of needle litter falls at the edge

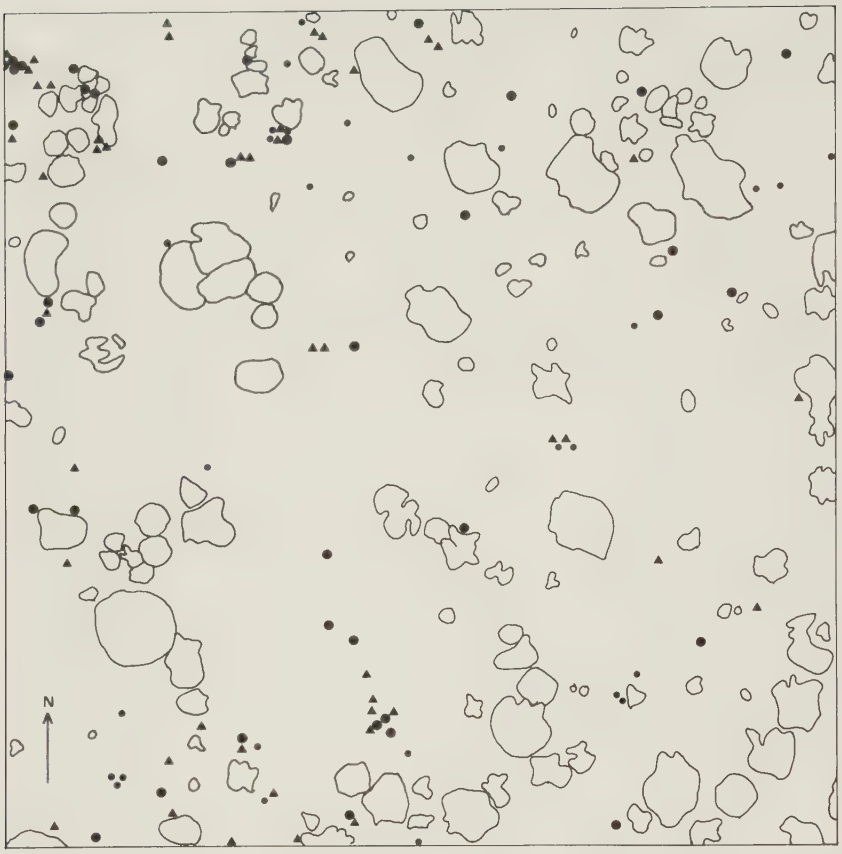


Fig. 21. Distribution of big junipers and seedlings within the control plot (50 x 50 m) in 1971—81. Seedlings which have colonized during the five-year intervals (1971—76 and 1976—81) are shown separately. Only specimens alive in 1981 are shown. — Alvar of Nedre Ålebäck.

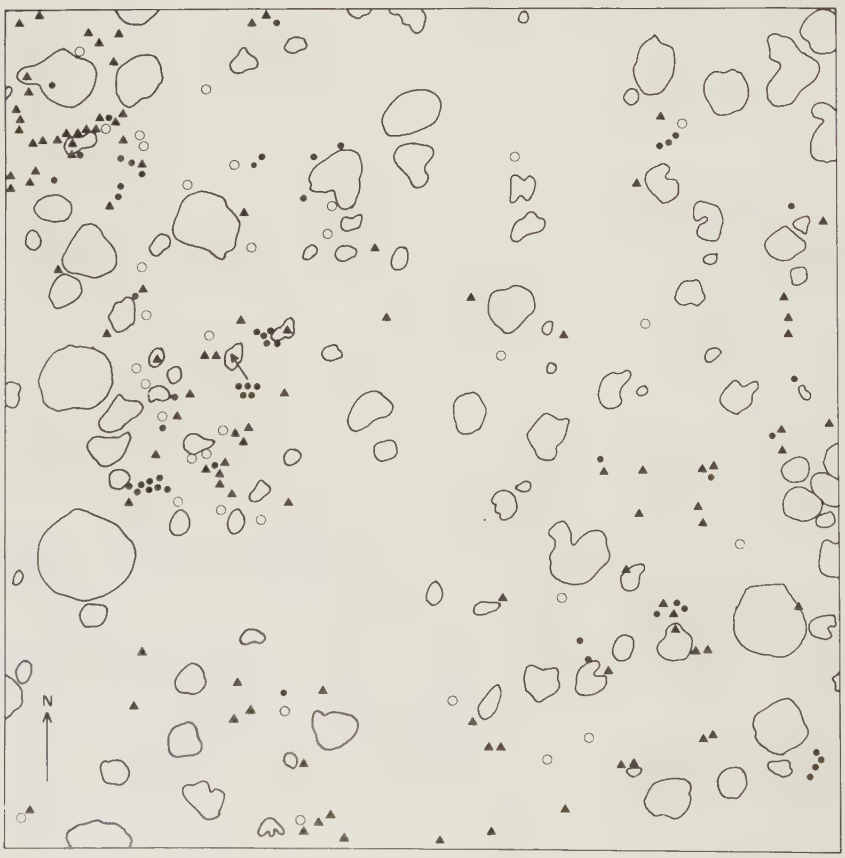


Fig. 22. Distribution of junipers before clearing in 1970, and new established seedlings in the test plot in five-year intervals (1970/71—1976 and 1976—81). The location of small seedlings present before the clearing and new established ones is shown. From 1976 only specimens alive in 1981 are shown. — Alvar of Nedre Ålebäck.

and brings a lot of acid material to the ground. Most of the lowest pH-values were obtained at a depth of 5—15 cm, where the buffering capacity of the soil seemed to be lowest. Exceptions were samples from deep soil localities or in places with a fissure under the sampling site. Under such circumstances the lowest values tended to be found at levels below 15 cm. At the levels closest to the limestone bedrock, pH-values were frequently increased, probably as a result of carbonates efflorescing from the rock and being circulated by water.

The material is too small for any reliable explanation of these differences to be proposed. Local variations in the soil could probably be one explanation, or changes due to different climatic conditions during the three years. Seasonal changes in pH have been demonstrated by, e.g., Czerwiński & Pracz (1978 p. 9). Another reason might have been the decomposition of dead root biomass, releasing acid material. Also local changes might have been brought about by colonizing plants.

6.1.4 Juniper growth in the control plot

In 1971 the control plot was mapped and heights and diameters were measured as in the test plot. The measured shrubs totalled 150, and in addition there were 40 small ones, thus being 190 in all. The test plot had 201 shrubs at the time of clearance. In 1976 the control plot was mapped again and measured. On that occasion 48 new shrubs were found. As one of the older junipers had died during the period the total number was 237.

In 1981 the measuring and mapping was repeated, showing 28 new junipers. During the 5-year period one old shrub (class I), one small shrub from 1971 and two small shrubs from 1976 had died. But one old shrub on the border was now included in the plot. Totally 262 shrubs were found in 1981 (Fig. 21).

In the test plot, 107 small shrubs were found in 1976 and 53 new ones in 1981, but one from 1976 had died. Totally 159 were found in the plot in 1981 (Fig. 22).

A comparison between the two plots concerning newly established shrubs gives interesting results. In 1976, 107 new shrubs were found in the test plot, but only 48 in the control plot. In 1981 the

Table 48. Number of shrubs in the control plot in 1971, 1976, and 1981, and mean values of height (cm) for each size class. One juniper (class I) died within each of the two 5-year intervals, the smallest junipers excluded. Junipers have grown into higher classes within the period. No new small junipers have been added. - Alvar of Nedre Ålebäck.

Class	I	II	III	IV
1971				
Number	63	40	32	15
Height	42.0	73.3	84.5	96.7
1976				
Number	55	42	34	18
Height	42.4	77.0	90.0	96.9
1981				
Number	39	54	28	27
Height	51.3	79.8	98.0	96.4

Table 49. Percentage increases of diameters and heights for junipers in the control plot in relation to class were calculated for the two time intervals 1971-76 and 1976-81. Within an interval, junipers remained in their original class but could be moved to another class for the next 5 years interval. - Alvar of Nedre Ålebäck.

Class	I	II	III	IV
1971-76				
Height	18	7	7	4
Diameter	27	11	7	5
1976-81				
Height	25	14	8	6
Diameter	20	11	7	5

Fig. 23. Junipers gather snow in drifts on their leeward sides, thus giving deeper snow cover, on average, in areas with junipers than in areas without. The drifts are formed by densely packed snow, which will last 1—2 weeks longer in spring than in the surroundings. — Alvar of Nedre Ålebäck. 10 March 1970.

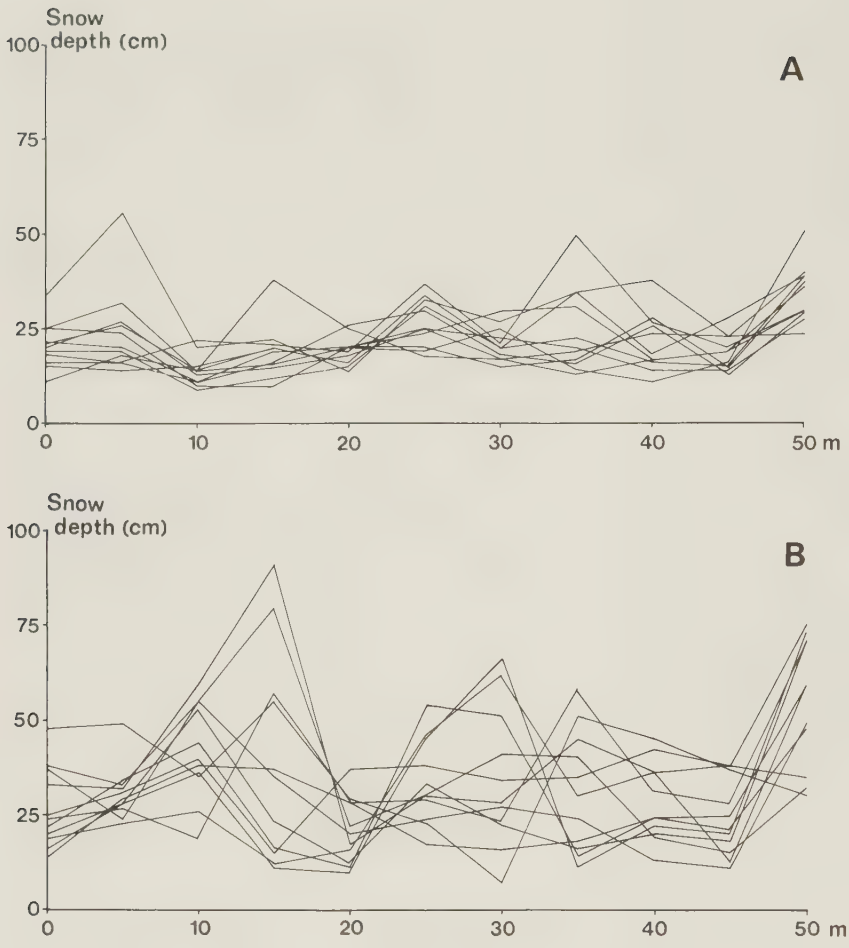


Fig. 24. Distribution of snow depth showing the locations of snow drifts within the permanent plots with junipers (7 March 1971). A. Test plot (junipers cut). Mean snow depth 22 cm, amplitude 9—56 cm. B. Control plot (junipers intact). Mean snow depth 33 cm, amplitude 7—91 cm. The plots are seen in south-north direction. — Alvar of Nedre Ålebäck.

numbers were 53 and 28. Juniper colonization in the test plot may have been favoured by release of nutrients from the dying roots, at least during the first 5-year period. As there are no other large shrubs in that plot the competition must be lower than in the control plot, where the struggle for water influences the survival of seedlings more negatively. In general, it is interesting to notice that a large number of seedlings have become established during these two intervals of five years, and very few of them have failed to survive.

The registrations also reveal that new juniper shrubs occur most frequently in places as far as possible from the old shrubs, in the open grass areas in between. The same situation was observed in Upper Teesdale, England by Gilbert (1980 p. 1022).

There is also a tendency for establishment in groups in some parts of the plots, the most obvious being in the test plot. Such aggregations of juniper seedlings have also been found in Poland in an investigation about changes in sex- and age-ratios due to various stages in the succession of juniper populations (Falińsky 1980 pp. 327 ff.). No such registrations of sex have yet been made in my investigation. Some of these groups can be referred to a certain time period of colonization. The settlements in open areas could be just a question of lower competition there, but also of biochemical inhibition (allelopathy) around the older shrubs. The colonization of open areas helps the junipers to cover an area fairly rapidly as small specimens grow faster than older ones (see below). It was interesting to note that a *Pinus sylvestris* appeared in the test plot after the clearing and is now 1.7 m high (1981).

In Table 48, results of investigations in the control plot are presented. In 1971 the values were similar to those obtained from the test plot (see Table 44), except for a larger number of measured

small junipers in the control plot. As the shrubs increased their diameter some of them have been moved to a higher class in 1976 and in 1981. For all three measuring years there is an increased height within the classes.

In Table 49 the percentage increase in growth is presented for each class in 1971—76 and in 1976—81. These figures show very clearly that shrubs of the small size classes increase their diameter and height much more, on average, than those of the large size classes. It is also observed that the diameter growth was larger in 1971—76 than in 1976—81, while the reverse occurred as regards the height growth. The highest shrub in the control plot (in 1981) is 1.85 m (no. 94). The largest shrub (no. 47) is only 0.65 m high, but has the diameters 490 and 495 cm.

The mean radius of shrubs in the stand was calculated, from which the stand area was obtained. In 1971 this area was 250 m^2, the smallest shrubs and seedlings being excluded. In 1981 the same stand had increased by 45% to 363 m^2. Thus 10% of the control plot was covered by junipers in 1971 and 14.5% in 1981 (test plot 11% in 1970). This 45% increase in 10 years indicates a rapid formation of a juniper scrub if no grazing is maintained.

Fig. 25. In spring the snow drifts close to junipers provide extra water for the vegetation and longer shelter against exposure to large daily temperature amplitudes. — Alvar of Nedre Ålebäck. 4 March 1972.

Table 50. Mean snow depths (cm) and amplitudes in a test plot cleared of junipers and in an uncleared adjacent control plot 1971-79. - Alvar of Nedre Ålebäck.

	Test plot		Control plot	
	Mean	Amplitude	Mean	Amplitude
1971-03-07	22	9-56	33	7-91
1975-03-19	14	8 21	18	11-41
1976-03-16	19	15 35	23	15-58
1977-01-05	12	5-30	19	5-51
1979-03-16	13	0 36	30	4-80
Mean/5 years	16	7-36	25	8-64

6.1.5 Snow cover and junipers

As the junipers in winter gather snow in drifts, on the leeward sides (Fig. 23), differences in snow depth between the cleared test plot and the control plot were investigated. In March 1971 snow depth in both plots were measured at intervals of 5 m, providing a mean value for 121 measuring points. Results from 1971 and four other years are shown in Table 50.

The area in which the plots are situated is exposed to strong winds, which may be indicated by the figures of the amplitude of the snow cover. A comparison of the mean values for five years shows that there was 56% deeper snow cover in the area with junipers than in the one without. One example of the snow distribution (1971) is given in Fig. 24. In that year, 50% deeper snow cover was measured in the control plot than in the test plot. Snow drifts were formed in the control plot giving a much wider variation in snow depth than in the other plot. The snow drifts generally consist of densely packed snow and thus last longer (1—2 weeks) in spring. The deeper snow and the drifts will give a longer-lasting snow cover for the plot as well.

A longer-lasting snow cover provides extra water for the vegetation in spring but also a longer-lasting shelter against exposure to large daily temperature amplitudes in early spring (Fig. 25). These influences will, of course, favour the juniper seedlings in the control plot, as well as its plant cover as a whole.

7 Aspects of grazing on the Stora Alvaret

7.1.1 Grazing animals

In the 19th century a fairly high grazing intensity was maintained on the Alvar due to the rising population. The animals were tended as there were few fences in the area, but people started to construct stone-walls in the first half of the century. The Alvar became increasingly enclosed in smaller regions belonging to various parishes (cf. 1.1).

Figures available from the 16th and 17th centuries show a large number of sheep on Öland. For sheep-grazing the northern part of the island was the most important (Ölands norra mot). In the southern part (Ölands södra mot) there were only 4 678 sheep in 1571 compared to 8 043 in the northern part. In 1641 the figures were 5 178 and 8 615 (Martinsson 1965 pp. 51 ff.). The same author mentions that the average farm using the Stora Alvaret had only few sheep. In southern Öland large parts of sheep pastures were located outside the Alvar.

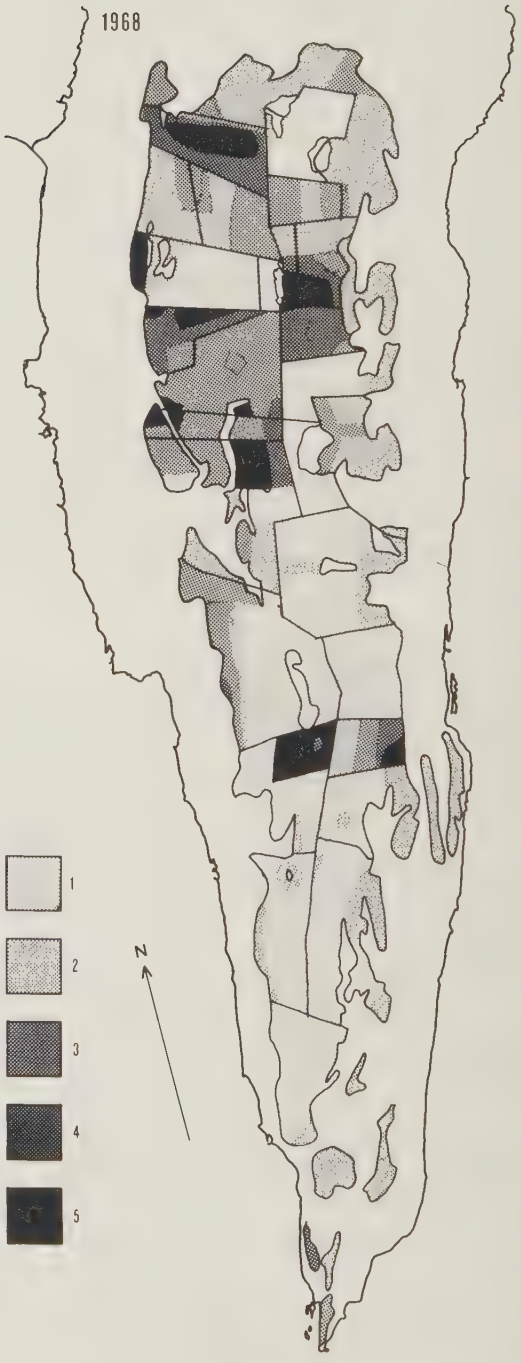
According to the figures above there were 12,721 sheep on the island in 1571 and 13,793 in 1641. The largest number was in 1865. After a slight decrease there is again a large number in 1917—19, but after that there was a continuous decrease until 1956. When the intensive sheep farming period started the figures increased drastically and were still very high in 1976.

Number of sheep on Öland for some years during the period 1865—1976

Year	No.	Year	No.
1865	18 094	1956	2 723
1910	13 203	1961	4 063
1917—19	16 415	1966	10 500
1927	12 226	1971	10 306
1944	8 972	1976	16 010

In 1963 the sheep farming companies had a total of 6 000 sheep in an area of 4 000 ha of fenced land on the Stora Alvaret. It was intended to manage 50,000 sheep on 50,000 ha, but this was never realized (Martinsson 1965 pp. 51 ff.).

The intensity of grazing on the Alvar was very different in various areas, as presented in a map (Fig. 26). Ljung (1970 pp. 36 ff.) gave a presentation of the com-



position of grazing animals and their number in two parishes (Vickleby and Mörbylånga) during 1865—1966. Information was compiled from *Sveriges officiella statistik*. The number of animals per parish is given from 1865 in 5-year intervals, with some exceptions. For these two parishes, figures for 1971 and 1976 have been added. Figures for Gårdby were also added (Fig. 27).

These figures exemplify the kind of grazing animals used in former days and their numbers. A trend of change in animal husbandry is found which is somewhat divergent for various areas, especially from the 1950's.

Cows, horses, sheep and oxen were the grazing animals in the 19th century. There were fluctuations in number of animals for various reasons. The failure of crops in 1867—68 might have been a reason for the decreased figures, most pronounced for Vickleby and Mörbylånga, at that time.

Increased amounts of cows and sheep around the 1880's may reflect the high population pressure on land before the emigration. Decreased figures towards the beginning of the 20th century might have been caused by the loss of population, but also by increased cultivation of former pasture land.

In all diagrams the numbers of oxen continuously decrease. In 1919 the last oxen are reported from Vickleby and Mörbylånga and in 1937 from Gårdby. Oxen were no longer used as draught-animals (Matzon 1975 p. 47). The curves after these years reflect a small increase of bulls (mostly young).

Also the numbers of horses show a decreasing trend, and in the 1960's they have almost disappeared, being replaced by tractors or other vehicles. Somewhat higher values for horses in the first decades of this century may find an explanation in an increased need of transporta-

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◄Fig. 26. Consequences of grazing on the Stora Alvaret in the 1960's, exemplified by the situation for various parts of the area in 1968. Key to the five degrees of change of the vegetation and soil caused by grazing (scale after Rosén & Sjögren 1973):

1. Slight or non-existent consequences of grazing. *(a)* Fragmentation by trampling animals of fruticulose lichens, such as *Cladonia* spp., *Cetraria* spp., *Thamnolia vermicularis,* cannot be observed or is very rare. *(b)* No wearing away from the limestone rocks of crustaceous lichens, such as *Verrucaria* spp., *Lecanora* spp., or of foliaceous lichens such as *Collema* spp. *(c)* Fragmentation of cushion-forming mosses, such as *Tortella* spp., *Schistidium apocarpum, Ditrichum flexicaule* is not observed or is rare. *(d)* High frequency in the *Sedetum tortellosum* of brightly coloured crustaceous lichens, such as *Toninia coeruleonigricans, Lecanora* spp., *Lecidea decipiens, Fulgensia* spp. (German: Bunte Erdflechten). *(e)* Flowering and fructification of vascular plants not restricted. *(f)* No or very slight grazing of shrubs (*Prunus spinosa, Potentilla fruticosa, Juniperus communis, Rosa* spp.). *(g)* Accidental presence of nitrophilous weeds from fields and cultural pastures. *(h)* Erosion of plant cover by trampling of grazing animals not observed. *(i)* Manuring by grazing animals is slight. *(j)* Polygon structures at the ground surface are not disarranged. *(k)* Grazing is strongly concentrated to *Avenetum* vegetation on gravelly ridges.

2. Small changes by grazing. *(a)* Fragmentation of lichens is rare. *(b)* Slight wearing away of crustaceous lichens. *(c)* Few fragmentated moss cushions. *(d)* Brightly coloured crustaceous lichens are rather frequent. *(e)* Flowering and fructification slightly restrained in the *Avenetum* community. *(f)* Local rather heavy grazing of shrubs. *(g)* Nitrophilous weeds are not frequent. *(h)* Erosion caused by grazing animals is very slight. *(i)* Local but rather considerable manuring by grazing animals. *(j)* Polygon structures disarranged. *(k)* Grazing mainly takes place in the *Avenetum* vegetation.

3. Rather far-reaching changes caused by grazing. *(a)* Fragmentation of lichens occurs frequently. *(b)* Local wearing away of crustaceous lichens. *(c)* Several moss cushions fragmented, displaced or turned upside-down, and thus moribund. *(d)* Brightly coloured lichens are rare. *(e)* Flowering and fructification restrained in all plant communities. *(f)* Locally scattered shrubs killed by grazing, over large areas. *(g)* The *Avenetum* shows a frequent inmixture of nitrophilous species. *(h)* Bare patches in the plant cover caused by trampling are rare. *(i)* Heavy manuring in all plant communities. *(j)* Polygon structures deranged over large areas. *(k)* Grazing rather evenly distributed between plant communities.

4. Far-reaching changes caused by grazing, locally reparable in the bottom layer only after about 50 years' cessation of grazing. *(a)* Fragmentation of lichens in all plant communities over large areas. *(b)* On all bare limestone rocks, far-reaching wearing away of lichens. *(c)* More than 75% of moss cushions disappeared or dislocated. *(d)* Brightly coloured lichens in *Sedetum tortellosum* very rare. *(e)* Restraint of flowering and fructification in all plant communities. *(f)* Over large areas, shrubs heavily grazed and specimens of *Potentilla, Prunus,* and *Juniperus* killed. *(g)* Very frequent inmixture (local predominance) of nitrophilous species in the Avenetum. *(h)* In all plant communities bare mineral soil patches in the plant cover, caused by trampling. *(i)* In all plant communities considerable manuring. Sheep manure is present in every dm^2 in the *Avenetum*. *(j)* All polygon structures deranged or regionally deranged. *(k)* Grazing pressure evenly distributed between plant communities.

5. Very far-reaching changes caused by grazing over large areas (bottom layer) reparable after more than 50 years' cessation of grazing. *(a)* Over large areas, far-reaching fragmentation of lichens, fragments blown away or trampled down into the mineral soil. *(b)* Crustaceous lichens on the limestone rock totally worn away. *(c)* Nearly 100% of moss cushions disappeared. *(d)* Brightly coloured lichens in moss cushions nearly absent. *(e)* Flowering and fructification heavily restrained in all plant communities. *(f)* Killing of shrubs over large areas. *(g)* Nitrophilous weeds have invaded the *Avenetum* and provide more than 50% of cover in large areas. A few vascular plant species of the original *Avenetum* have survived. *(h)* Bare patches in the plant cover caused by trampling are frequent in all plant communities. Erosion of mineral soil is considerable locally. *(i)* Considerable manuring in all plant communities. *(j)* No polygon structures remain. *(k)* Grazing pressure nearly equally distributed on different plant communities. Weak grazing preference for the *Avenetum* due to the invasion of fastgrowing nitrophilous species.

Fig. 27. Numbers of various kinds of domestic animals found in three parishes on Öland during 1865—76 (mostly in five-year intervals). A. Gårdby, B. Mörbylånga and C. Vickleby. Note the different scales in B and C.

——— sheep
– – – horses
–·–·– cows incl. heifers and calves
..... oxen and bulls

tion when some factories opened in Öland, but also as a replacement for oxen.

From the end of the 1920's there is also a decrease in the numbers of cows until the 1950's, except for Gårdby which maintains the same level. In the 1950s the rearing of young cattle for meat production increased the figures, most pronounced in Gårdby but also in Mörbylånga.

Concerning sheep, they also have a decreasing trend, with a slight increase around 1920. In 1951 only 34 sheep altogether were recorded in these three parishes. In the early 1960's a tremendous change took place when large-scale sheep farming started. In 1966 there were 1 980 sheep in Vickleby, 1 263 in Mörbylånga, and 7 in Gårdby. In Vickleby the number obviously was too high and has been reduced. Mörbylånga had adapted to a somewhat lower level from the beginning, which after a decrease rose again in 1976.

However, not all animals in these diagrams influenced the vegetation of the Alvar, but most of them had an influence of one kind or another. In this century the number of dairy cows has decreased totally, also on the Al-

var, but a large number of heifers have replaced them in some areas.

Sheep are the main grazers today, being better managed by the use of folding, both on the Alvar and elsewhere, than they were during the early days of the large-scale sheep farming. The period of grazing is shorter, as the sheep are fed in the folds and sheep-barns during the winter.

The profitability is now maintained at an acceptable level. The meat gives the best income (Alvelid 1974 p. 253).

In 1976 most of the 16,010 sheep were found in the southern part of Öland, in the neighbourhood of the Alvar (Mörbylånga, Vickleby, and Segerstad). However, the largest number locally is found south of the Stora Alvaret in Ottenby (parish of Ås) where 3 815 sheep were kept in 1976. Ottenby has a sheep farming tradition ("schäferi") since the 16th century.

It must be stressed that the large number of sheep today use only limited areas of the Alvar in comparison with the 19th century, thus creating a higher and different pressure on the vegetation than earlier.

Fig. 28. The sheep farming companies constructed sheep-barns and folds where sheep were kept and fed in winter. Waterholes were dug or blasted in several alvar areas in order to make the ground water available to the animals. Waterhole in a thick gravelly deposit. — Alvar of Karlevi. November 1969.

7.1.2 Some consequences of sheep farming on the Stora Alvaret during the 1960's and 1970's

Very heavy grazing of the Stora Alvaret by sheep started in 1959 (Fig. 28). Five years later there was a reaction from nature conservancy interests against damage to vegetation caused by the grazing. In 1964 some nature reserves were suggested by the late Prof. G.E. Du Rietz (Institute of Ecological Botany, Uppsala Univ.), and in 1965 Dr. E. Sjögren (same Institute) started a regional survey of changes of vegetation in large areas of the Alvar. These records formed reference material for my investigations which started in 1969, preceded by a pilot study in 1968.

Regional surveys

Regional records with the purpose of presenting the status of the various fenced areas within the Alvar were carried out by Sjögren in 1966—71. He created a five degree scale, including changes in the structure of vegetation and soil caused by grazing (Rosén & Sjögren 1973). The scale is explained in Fig. 26.

The most heavily sheep-grazed areas are found in the northern part of the Alvar where most of the grazing connected with the big sheep-farming companies took place, with a few exceptions. A continuous increase in vegetation changes occurred until 1968 in these areas. Then a regeneration of the vegetation took place as the grazing intensity decreased, for example, due to economic problems for the companies.

However, a few areas in the northern part of the Alvar remained seriously changed by grazing after 1968. At that time, large formerly heavily grazed areas had recovered fairly well as regards the field layer, while the shrubs and especially the bottom layer would need a much longer period of recovery. At the end of the period for regional mapping, sheep grazing had decreased or totally ceased in these severely changed areas.

Changes of vegetation close to folds and sheep-barns

As a part of the nature conservancy project "Relations between vegetation and grazing", a special investigation was carried out in 1968 by Elisabeth Ljung. The aims were to compare areas within, or close to folds, with areas less grazed in respect to composition of the plant cover in the *Avenetum*- and the *Festucetum*-vegetation.

Six different folds were investigated by means of transects from a central point and out to a distance of 150—400 m. Recordings of species and their cover were made at intervals of about 25 m at the beginning of the transect and then at 50 m intervals.

Within each interval four plots of 1 m^2 were analysed.

A fairly comprehensive summary of the results by Ljung (1970) will be given below, being necessary for comparisons with results obtained by the author:

Original plant communities become considerably changed after a period of heavy sheep grazing. Those changed most are the areas where sheep gather or stay during the winter, as in folds or around sheep-barns. In these places colonization by anthropochorous taxa took place to the extent that original plant communities totally disappeared (Plate 4:1). The anthropochorous taxa listed below occurred regularly around sheep-barns and places where hay was stored:

Atriplex patula
Capsella bursa-pastoris
Chenopodium album
C. bonus-henricus
C. glaucum
Cirsium arvense
C. vulgare
Descurainia sophia
Matricaria inodora
M. matricarioides
Odontites verna
Plantago major
Polygonum aviculare
Rumex crispus
Senecio vulgaris
Sisymbrium officinale
Stellaria media
Taraxacum vulgare coll.
Thlaspi arvense
Trifolium hybridum
T. pratense
Urtica dioica
U. urens
Apera spica-venti
Bromus inermis
Dactylis glomerata
Elytrigia repens
Festuca pratensis
Lolium perenne
Poa annua
P. pratensis coll.

Normally these taxa are found on ruderal ground or along roads. Closest to the sheep-barns *Urtica dioeca, U. urens, Cirsium arvense,* and *C. vulgare* were found, as they seem to be favoured by high contents of nitrogen in the soil caused by droppings.

Floristical gradients due to grazing are found in the transects. Anthropochorous taxa are very frequent and they often appear with a high cover degree in the plots close to sheep-barns. Concerning grasses, original taxa such as *Arrhenatherum pratense, Briza media, Festuca* spp. and *Agrostis* spp. are often replaced by *Dactylis glomerata, Elytrigia repens, Lolium perenne, Poa annua,* and *P. pratensis.* Step by step the number of taxa increases with the distance from the sheep-barn as original taxa are added and sociologically alien taxa disappear. Original taxa which seem to have a high tolerance to grazing and competition from alien taxa are:

Achillea millefolium
Anthyllis vulneraria
Cerastium pumilum
Crepis tectorum
ssp. *pumilum*
Filipendula vulgaris
Galium verum
Herniaria glabra
Hieracium pilosella
Sedum acre
S. album
Sisymbrium supinum
Trifolium campestre
Bromus hordeaceus

Less tolerant are taxa such as:

Allium schoenoprasum var. *alvarense*
Galium triandrum
Globularia vulgaris
Helianthemum nummularium
Oxytropis campestris
Potentilla tabernaemontani
Prunella grandiflora
Satureja acinos
Thymus serpyllum
Veronica spicata
Agrostis canina
A. stolonifera
Arrhenatherum pratense
Briza media
Carex ericetorum
Festuca ovina
Phleum phleoides

There are, of course, differences between the folds, but these could be more related to differences in grazing intensity than to differences in environmental factors.

Mosses start to appear in plots at a distance of 20—100 m from the sheep-barns, with exception of *Bryum argenteum,* which is found even closer. Taxa as *Bryum argenteum, Pohlia nutans,* and *Ceratodon purpureus* seem to appear first. They should not be considered as characteristic taxa for the Alvar. Among the characteristic mosses *Camptothecium lutescens, Rhytidium rugosum, Ditrichum flexicaule,* and *Schistidium apocarpum* seem to withstand grazing better than *Tortella tortuosa, T. inclinata, Encalypta streptocarpa,* and *Fissidens* sp.

Lichens do not appear closer than 80—230 m from the sheep-barns. The lichens that suffer most from grazing are the following (in the *Festucetum*): *Thamnolia vermicularis, Toninia coeruleonigricans, Fulgensia bracteata,* and *F. fulgens.* These are found only at the ends of the transects while *Cetraria* spp. (in the *Avenetum*) are found about 100 m closer to the sheep-barns.

A large number of dead shrubs were found in the folds, most probably due to the grazing. Figures around 80% killed shrubs were recorded for junipers and *Potentilla fruticosa* (Plate 4:3). Further information on tolerance to grazing for various taxa are given by Steen (1954, 1956, 1958a, b).

7.1.3 Remarks on tolerance of vegetation to grazing in general

Numerous other taxa may be considered as having tolerance to grazing. Phanerogams such as *Ranunculus illyricus, Orchis ustulata, O. mascula, Dactylorhiza sambucina, D. incarnata, Anthericum ramosum,* and *Helianthemum oelandicum* frequently disappear from areas grazed by sheep.

Sjögren (1971 p. 491) stated that species with a weak root system easily become pulled up by the sheep, such as *Viola pumila, Satureja acinos, Luzula campestris,* and also *Anthyllis vulneraria.* The latter species was not considered to have a low grazing tolerance by Ljung, but should have been

Fig. 29. Plant communities on thin soil or on bare rock are easily destroyed by trampling animals. Moss and lichen communities were totally destroyed in the Vickleby Storkarst area after only a few years of intensive sheep grazing in the 1960's. — Alvar of Vickleby. 16 October 1968.

included as the root easily breaks about 1—2 cm below the ground. *Globularia vulgaris* suffers in grazed areas but in places is very frequent outside the fence surrounding an area grazed by sheep. To some extent this species could be used as an indicator species of grazing intensity (Martinsson 1965 p. 51).

Plant communities on very thin soils or on bare rock are the ones most easily destroyed. These communities are dominated by mosses and lichens which, in a dry condition, easily become fragmented and then blow away. The most serious effect on them is not the grazing itself as these communities have very low grazing value. Some are not grazed at all. The effect of trampling by the sheep is much more remarkable. Moss cushions of *Tortella* spp. and *Schistidium apocarpum* on bare rock may disappear totally (cf. Plate 3:6, Fig. 29).

In the *Festucetum* the *Festuca* tufts are surrounded by bare soil. During spring (or autumn) the frost-induced soil movements often lift these tufts up, forming pillars of soil with *Festuca* on the top. Trampling on or around these tufts quickly destroys the plant cover, leaving it open for wind or water erosion. This damage to the tufts could take place either in dry conditions or when the calcareous soil is saturated by water in spring and autumn (or sometimes in connection with heavy rains in summer).

Tussock vegetation is also broken up by trampling. Starting with some open soil patches on one side the erosion may eventually complete the damage of the entire tussock (Sjögren 1971 p. 492).

Erosion induced by grazing appeared in several widespread places, but fortunately becoming severe only locally in limited areas. This, however, naturally has not got the dimensions of the erosion that has taken place due to grazing in Mediterranean areas or in the highlands of Iceland.

Hoof pressure (standing) for sheep is 0.94 kg/cm^2 and for cattle 1.56 kg/cm^2 (Smith 1980 p. 257), the two main kinds of grazing animals in the Alvar. For young cattle these figures may not differ very much.

As the sheep has a smaller hoof it will damage a moss cushion more easily than the hoof of cattle, as the former tends to separate the cushion, while the latter often just presses it. In many areas the soil is compacted by trampling, which is also negative for plant production. The manuring effect has been mentioned above.

The habit of sheep to walk in the same tracks between different areas will create sheep paths. Bare soil patches around water-holes and salt-stone tables, all caused by trampling, will, together with these paths, supply colonization areas for anthropochorous taxa and may also become subject to initial stages of erosion.

The damage to the plant cover in the most heavily grazed areas was increased by vehicles used for sheep farming or by blastings for new water holes. Some interesting and variable areas of value to

science were more or less destroyed concerning the plant cover during a few years of grazing. One of these areas was Vickleby Storkarst—a large, well-known karst area (Fig. 29).

It is not only the plant cover which is changed due to grazing. New conditions are created, such as soil compaction, bare soil patches, manuring, microclimatic changes due to a shorter sward of graminids, and killed shrubs, severely affect the composition of the invertebrate fauna which could be drastically changed. Such changes may affect the decomposition rate in various ways. Smith (1980 pp. 271 ff.) gives a short review of literature on invertebrates in limestone and chalk grasslands in Great Britain. Further information is given, e.g., by King & Hutchinson (1976 pp. 41 ff.) and Olechowicz (1974 pp. 589 ff.). I am not aware that any investigation of this kind have been published concerning the Alvar. However, there are probably changes in the invertebrate fauna of the Alvar which correspond to results obtained in other chalk or limestone areas in central or northern Europe.

7.1.4 Selective grazing

Grazing by sheep or cattle is selective. Many authors, including Arnold (1964 p. 135), report that sheep and cattle select leaf in preference to stems, and green (or young) material in preference to dry (or old). The preference is maintained for various reasons. Green material and leaves contain more nitrogen, soluble carbohydrate and phosphate, and less fibre than stems and old material. The preference may also be explained by the chemical composition of selected plants (op. cit).

However, there are indications that a preference may be related more to dry matter, phosphate, and soluble carbohydrate contents and less to fibre and nitrogen contents in particular species or strains. A preference by sheep between two species could be distinct even with minor differences in chemical composition or stage of growth (op. cit. p. 136). It is also known that in vegetative stages *Arrhenatherum* spp. are preferred by sheep to *Festuca* spp. (op. cit).

A distinct selectivity is noticed on the Alvar concerning *Vincetoxicum hirundinaria,* which is avoided, although young shoots are grazed now and then. It was also seen that grazing preferentially took place in the *Avenetum* and the *Festucetum.* In the early grazing season (May) sheep and cattle very frequently graze the green vegetation around junipers. Vegetation in such places at that time of the year is favoured by wind shelter and extra water supply from recently melted long-lasting snow drifts.

The *Sesleria* community (cf. *Molinietum alvarense* Albertson 1950) is less frequently grazed, probably due to the high dominance of fairly stiff taxa such as *Carex flacca* and *Sesleria coerulea.* However, in 1975 heavy grazing was noticed in that community in some areas of the Alvar. The summer of 1975 was very dry and the sheep probably sought green and fresh material which nearly only could be found in shallow depressions in the Alvar where the *Sesleria* community occur. Dry parts of the community were less grazed (Plate 1:3).

Grazing animals select their diet mainly from the green parts of the vegetation. When the percentage of dry material in pastures increases they are not able to feed only on green components. The preference for green plants is still noticeable although the selectivity is weakened under such conditions (Arnold 1964 p. 137). This might explain the grazing in the *Sesleria* community.

In the Alvar no special studies have been carried out on selectivity of diet, but it has been frequently noticed that the heavier the grazing the less selective it turns out to be as a result of decreased standing crop in preferred communities and by colonization of less attractive taxa (cf. the damage scale by Sjögren, point *k* in Fig. 26).

Selective grazing alters the composition of plant communities and forces the animals to change their choice of material (Arnold 1964 p. 137). Such changes in the composition of plant communities are locally distinctly pronounced in the Alvar (cf. 3.2.1). The selectivity thus could be altered both due to the level of grazing intensity and the long-term gradual change in the composition of a plant community. Also changes during the season within a certain taxon or in the composition of the pasture induce changes of selectivity.

In the Alvar area of Kleva a dominance of *Bromus hordeaceus* was noticed in early summer, but as this species is almost neglected by the sheep, a

part of the standing crop is left unused (Plate 4:2). It is also noticed that *Juniperus communis* is occasionally browsed by sheep even when enough feed is available. In a heavier grazing regime, however, they become frequently overbrowsed and killed by the sheep.

The less feed available, the longer the time needed for daily food intake by the animal (Arnold 1964 p. 142). A short report by Swendsén (in Sjögren 1972) gives figures of 9—10 hrs grazing on average per day for sheep on the Alvar. Short days are compensated by grazing in the dark (up to 10% extra). The need of energy in spring is larger due to feeding the lambs. An interesting analysis of annual choice of food was made in Scotland by Martin (1964 pp. 137 ff.) who studied the composition of faeces. However, his results cannot be transferred to the Alvar as the conditions are different.

Diurnal grazing habits must also be taken in consideration. Some areas could get a higher intensity than others due to different reasons. Such areas could be those preferentially grazed but also areas where the animals rest during the day or where they stay during the night. In some of these places the amount of droppings may be remarkably high.

In the Alvar the sheep find wind shelter along the stone walls. They also frequently rest in the slightly elevated parts of the Alvar (in the *Avenetum*), where they have good possibilities to discover presumptive enemies. A detailed mapping of the home range behaviour in hill sheep was carried out by Hunter (1964 pp. 155 ff.), who stresses the importance of understanding social behaviour by sheep in relation to topographic and vegetational variations. This is valuable knowledge for management purposes.

Altogether, selectivity in sheep grazing in combination with behaviour is a very complex matter. Differences from place to place due, for example, to vegetation, climate, and kind of animals, make it very difficult for a result to be considered as valid from one area to another.

7.1.5 Vegetation recovery time

The recovery of vegetation after grazing can be seen from different points of view. Regrowth of single plants after defoliation is one aspect and regeneration of a plant community after changes in composition due to grazing is another. Both aspects are dealt with below.

According to Alcock (1964 pp. 25 ff.), defoliation of a certain plant after grazing will decrease the leaf area ratio, the relative growth rate, the carbohydrate content and the net assimilation rate. After a few weeks of regrowth the leaf area ratio and the net assimilation rate increase and provide a higher relative growth rate. The latter reaches a maximum after a few weeks, and is higher than in the ungrazed plant. It remains higher for several weeks. Thus, grazing decreases the productivity, but later stimulates it to a higher level. Translocations of carbohydrates are supposed to be important for the regrowth. For defoliation by grazing, see also effects of wind speed (cf. 2.2.5).

The proportion of roots decreases after defoliation (op. cit. pp. 27 ff.). Consequently, the nutrient uptake becomes lower in the initial stages of regrowth, which also decreases the energy content in the plant. A short period (2—3 days) of grazing and a long period (3—5 weeks) of recovery give optimal use of a pasture (Steen 1961 p. 9). This suggests that a rotational grazing regime should be used on the Alvar, although very short periods in each fold are not realistic to suggest from a practical point of view.

Today, ten years after the regional mapping of the Alvar was completed, a fairly good recovery and colonization of junipers and other shrubs has taken place in earlier severely grazed areas. The most distinct regeneration is, of course, found in areas now with weak or no grazing at all. In others, the recovery is slow although a moderate grazing is now maintained. The same applies to the field layer as a whole. The bottom layer, however, needs much more time. Many taxa are still absent, or have not yet succeeded in recolonization due to the alien taxa favoured by grazing.

The time needed for recolonization of some nearly or totally eliminated taxa in the former grazed areas will, of course, be dependent on the present sources of seeds within the area (including the seed "bank" in the soil) or close to it. The type of plant community is also most important as well as the earlier degree of maximum damage. A much longer time is needed for moss- and lichen-rich communities than for the *Avenetum*.

An extremely long time is needed for recolonization of *Tortella* cushions on bare rock, or to recolonize a variably composed cover of taller lichens. Sjögren (1971 p. 493) predicts a period of more than 100 years for the full recovery of moss communities to the shape they had before the overgrazing started (cf. Plate 3:6). On bare rock the growth rate of crustaceous lichens is fairly well known. A crust of *Lecanora calcarea* with a diameter of 20 mm will take 25 years to develop (op. cit.).

In this perspective the vegetation of the Stora Alvaret, comprising all sorts of taxa, was obviously severely damaged for a long period of years in relation to a few years of heavy overgrazing.

8 Features influencing management for conservation

8.1.1 Dynamic aspects of trees and shrubs on the Alvar

In the late 19th and early 20th centuries, when grazing still was heavy on the Alvar, it was not easy to realize that grazing was very important for retention of the character of the landscape. Many scientists pointed out the thin soil layer, bad drainage conditions and frost-induced soil movements as the most important reasons for the lack of woodlands on the Alvar (Steen 1958a pp. 35 ff.).

However, when there was a decrease in grazing intensity in the early decades of this century it became obvious that there were close connections between grazing and invasion of shrubs and trees on the Stora Alvaret. Steen (op. cit.) gives a review of opinions and works on these questions, a few of which can be mentioned. Sterner (1955a p. 68) considers the changes taking place in Öland as due to decreasing numbers of grazing animals and less cutting for firewood: "Not for centuries, or even thousands of years, has the wild vegetation been able to develop as it does today, free from cultural influence. Forest trees recolonize with incredible speed areas from which they have been expelled for centuries. This process is now occurring also on Stora Alvaret."

In an interview (Johansson & Larsson 1978 pp. 124 ff.), an old farmer, Einar Eklöf, recalls that in his childhood (around 1900) he never would have expected trees on the Stora Alvaret. Having been away for some years, he returned in 1924 to the Alvar (at Skarpa Alby) and found single pines and birches in the area. At that time very few junipers were found but today the area has become densely invaded. The *Pinus sylvestris* plantations from around 1900 form today isolated dense woods.

Such plantations were regarded negatively by Du Rietz (1921 p. 83) as they changed the open character of the Alvar. Hagberg (1955 p. 264) was concerned about the rate of growth of shrubs and pines in the Alvar, expressing the hope for a renaissance in sheep-farming.

Sterner (1955d pp. 316 ff.) reports that in areas with deep till or littoral material, *Pinus sylvestris, Picea abies,* and *Betula verrucosa* spontaneously form dense stands. At these places junipers also frequently form dense shrubs which do not occur in unfavourable areas with thin soils and frost-induced soil movements.

A limiting factors for junipers (in addition to grazing) is the severe drought that irregularily occurs, killing a large number of shrubs. Also attacks by caterpillars occasionally kill or injure junipers (Sterner 1949 p. 190). It was predicted that large areas will become covered by mixed forest within a few decades (op. cit. pp. 170 ff.).

From the above and from my own experiences over the last decade, there is no doubt that there are close relations between grazing and vegetation structure in most of the Alvar communities.

Suitable conditions for junipers to establish new seedlings have been discussed by many authors. Pettersson (1950 p. 6) mentions from Gotland that *Juniperus communis* apparently is favoured by moderate grazing. Among others, Ward (1973 p. 179) noticed that seedlings occur on bare ground with reduced competition and no intensive shading. Gilbert (1980 p. 1022) found that optimum conditions for establishment of seedlings will occur during a phase of heavy grazing and not just after. Using an experimental approach, Fitter & Jennings (1975) studied the effect of sheep grazing on juniper seedlings. They also mentioned bare ground, usually a result of heavy grazing, as important for germination. A light grazing in summer reducing the competition between seedlings and grasses, tall herbs and shrubs was considered as desirable (op. cit. p. 641).

In my experimental area there was extensive grazing by cattle before the two big plots with juni-

Fig 30. *Picea abies* regenerates in two ways in the Alvar, by seeds and by vegetative regeneration. The creeping branches of spruce develop adventitious roots and then turn into an erect growth form, thus providing a screen of new stems around the matur tree. Alvar of Gynge. 6 September 1981.

pers were fenced in. I agree with the opinions above that it is easier for junipers to establish in a low, grazed vegetation than in a dense sward. However, after germination on the Alvar, a less grazed or ungrazed vegetation will provide good shelter for the seedlings against frost and wind. The dense sward will also give better shelter to the seedlings due to a longer-lasting snow cover than in grazed areas. After a few years the seedlings start to grow quickly if they are not disturbed by grazing.

The increased sward in my plots might have interfered with establishment of new seedlings as there were fewer new seedlings in the last five-year period than in the first one (cf. 6.1.4). If so, no grazing at all ought to be better than weak grazing in order to delay invasion by new seedlings. In the present case, already established seedlings become favoured.

Little is known about dispersal of *Juniperus communis* seeds, but birds are probably important (Ward 1973 p. 179). Crows, thrushes, gallinaceous birds, hares, and sheep are mentioned by Vedel (1961 p. 148).

As junipers colonize open areas between old shrubs they cover an area quickly (cf. 6.1.4). *Juniperus* is known to regenerate with seeds, as stressed by Blomqvist (1911 pp. 56 ff.). One report by Lemberg (1933 p. 95) mentions a case where junipers in a dune area in Finland developed adventitious roots from branches covered by sand. Such roots have not been found on the Alvar although many of the shrubs show both prostrate as well as erect and intermediate growth forms.

Turesson (1961 pp. 440 ff.) considers it possible that the colonies of *Juniperus communis* on Öland and Gotland are genotypical variants and not mere modifications. He also mentions some other cases of vegetative spread of junipers (op. cit. p. 442).

The question of strategies for regeneration also applies to other tall taxa on the Alvar, such as *Picea abies*. It spreads in two ways, by seeds and by vegetative regeneration. Frequently, long creeping branches from spruce develop adventitious roots and then turn into an erect growth form, thus providing a screen of new stems a few metres around the mature stem (Fig. 30).

Lange (1979 pp. 106 ff.) discussed the role of microclimatic conditions for establishment of an elfin forest. He considers that many young trees in wind-exposed areas with warm soil form a layer of twigs stretching further away than the other branches. He called that feature a microclimatic carpet, formed by buds being favoured near the

ground due to heat resources in the soil, which could occur during the growing seasons in areas with drought and cold winds. He gave some examples from the northern part of Öland.

The growth of spruce on the Alvar, mentioned above, might be related to that phenomenon, but it is more uncertain whether the prostrate growth forms of shrubs as *Juniperus* and *Cotoneaster integerrimus* can be related in the same way.

There is no doubt, however, that microclimatic conditions are created within the juniper shrubs where often seedlings of *Rosa* spp., *Sorbus intermedia,* and occasionally *Prunus spinosa* establish and grow. They receive sufficient shelter against wind, frost and grazing during their first sensitive stage of development. Even without that shelter, a rapid colonisation of the above mentioned taxa, as well as *Betula verrucosa, Picea abies,* and *Pinus sylvestris,* will take place in a weak grazing regime. The occurrence of *Rosa* species on the Alvar in decreasing order is as follows (Örjan Nilsson, pers. comm.): *Rosa canina, R. villosa* ssp. *mollis, R. dumalis,* and *R. rubiginosa.*

A mixed shrub and woodland area clearly is capable of developing—and indeed has developed—in areas with deposits of till or littoral material, as predicted by Sterner.

As mentioned above, there is a regulating and limiting factor for the survival of shrubs and trees on the Alvar due to supply of water in different sites. During extremely dry years some trees and shrubs are killed by drought. Water as a limiting factor also appears when a tree reaches a certain size. The water supply, then possibly being too low, would cause the tree to die or lead it to adapt to a smaller size by losing branches and adopting slow growth. Pettersson (1958 pp. 54 ff.) reports increased drought injuries on junipers in Gotland which might be correlated to decreased grazing intensity. Shrubs probably suffered from excessive transpiration when the shoots were not limited by grazing.

Junipers seem to withstand drought fairly well. Most of them survive and regenerate after a period of severe drought. Due to competition for nutrients and water they grow very slowly once they have reached the size adapted to a certain site.

When such an invasion of shrubs and trees takes place in former open vegetation, quite different conditions will develop for plants and animals. Microclimatic, floristic, faunistic and numerous other changes will occur. Many of the characteristic taxa of the Alvar, frequently growing also in the *Avenetum,* will find unsuitable biotopes and nearly disappear in these scrubs. On the whole, it will become increasingly difficult for them to find suitable areas on the Alvar for survival. In addition, large areas will become useless for grazing in the future.

8.1.2 Energy content of standing crop in the Avenetum and the Festucetum

Field layer samples

For calculations of stocking rate it is necessary to know the metabolizable energy content in the herbage. As the *Avenetum* and the *Festucetum* are preferentially grazed, samples were taken from several parts of the Alvar once a month from May to November 1972 in grazed and ungrazed *Avenetum* but only in ungrazed *Festucetum* (5 subsamples per type and month).

The choice of samples from both the grazed and ungrazed *Avenetum* and the ungrazed *Festucetum* was related to the knowledge that changes in composition of vegetation take place. These changes due to grazing are more pronounced in the *Avenetum* than in the *Festucetum* (cf. Chapter 3).

Analysis and calculations were done according to den Braver (1969 pp. 921 ff.). The results are given below in Table 51.

The content of crude protein was found to be higher in the *Avenetum* than in the *Festucetum,* probably due to a higher percentage of herbids in the *Avenetum.* It is also higher in grazed than in

Table 51. Crude protein (%), digestibility (%) and energy content (Mcal/kg) obtained in monthly vegetation samples from the Stora Alvaret (May November 1972) of Avenetum and Festucetum.

	Ungrazed Avenetum			Grazed Avenetum			Ungrazed Festucetum		
	C.prot.	Dig.	Energy	C.prot.	Dig.	Energy	C.prot.	Dig.	Energy
M	9.7	62	2.2	11.7	63	2.3	5.3	51	1.8
J	10.6	62	2.2	10.2	62	2.2	5.4	53	1.9
J	9.5	62	2.2	8.6	62	2.2	5.5	55	2.0
A	8.5	61	2.2	8.3	62	2.2	5.8	48	1.7
S	8.6	59	2.1	10.7	63	2.3	5.7	49	1.7
O	8.1	60	2.2	9.5	66	2.4	5.3	49	1.7
N	7.3	58	2.1	8.9	62	2.2	5.0	44	1.5
Mean	8.9	61	2.2	9.7	63	2.3	5.4	50	1.8

ungrazed *Avenetum* for same reason. The same pattern is also found for digestibility and energy content. Thus the *Avenetum* is more valuable for grazing than the *Festucetum*. The higher values for grazed *Avenetum* are related to a smaller amount of necromass and a higher content of herbids in this regime than in the ungrazed one. The fertilization experiment showed that graminids contain less crude protein than herbids and dwarf shrubs.

A tendency for values to slightly decrease at the end of the growing season, as well as a fluctuation within the season, was found. Crude protein variations are most pronounced for the *Avenetum*, which is probably related to pronounced changes in the share of herbids during the season. Dry periods giving a high necromass content in the samples and seasonal variations of soil properties are also involved.

Consequently, it is important to take samples in various periods of the season to obtain representative values over a longer period. A single analysis of, e.g., digestibility, may give misleading figures for further calculations of stocking rate.

Juniper samples

As junipers are browsed by sheep a few analyses were done on current-year shoots and on current-year shoots plus older parts. Samples were collected from various junipers on three occasions during the season (May, July and September). Current shoots both with and without part of the older branches (about 10 cm) were used. The results of the double analyses are shown in Table 52.

Crude protein content is higher in current shoots. It decreases from May to September. The ash content is lower in the current-year shoots as they have not yet lignified. In current shoots, the phosphorus (P) level seems to be higher but calcium (Ca) is lower. In July, digestibility and metabolizable energy seem to be higher in current shoots than in older.

Sheep are able to get some additional energy by browsing on junipers, especially current-year shoots, if the field layer is overgrazed.

However, sheep frequently browse juniper for other reasons. They may regulate the digestion by browsing leaves of deciduous shrubs or (current) shoots of junipers, increasing the dry matter part of the feed. Lack of grazing possibilities in very early spring and late autumn may also induce browsing on shrubs (Brelin pers. comm.).

Table 52. Analysis of current shoots and older parts of junipers in the Stora Alvaret on three occasions (May, July, September) in 1973, concerning dry matter (DM), crude protein (%), ash (%), Ca (%), digestibility (% of DM) and energy content (Mcal/kg).

	DM	Crude prot.	Ash	P	Ca	Dig.	Energy cont.
May							
current	94.7	9.9	4.8	0.17	1.62	41	1.4
current + old	95.3	7.9	5.1	0.14	0.76	42	1.4
July							
current	95.2	9.0	4.3	0.18	1.49	39	1.3
current + old	95.5	7.8	4.9	0.13	1.72	30	0.9
September							
current	95.6	8.2	4.5	0.15	1.59	34	1.1
current + old	95.6	7.3	5.0	0.13	1.81	32	1.0

8.1.3 Grazing intensity in the Alvar

The far-reaching changes of vegetation in the Alvar, mainly in 1960's, were caused by overgrazing. Some sheep farmers who rented land were not aware of a suitable grazing intensity for various plant communities.

If extreme changes in the composition of vegetation are to be avoided in the future a balanced grazing must be considered. The stocking rate must be adapted to the available amount and the energy content of the feed.

The energy content of the *Avenetum* and the *Festucetum* has already been discussed (8.1.2), but the figures for standing crop are not as clear. In ungrazed vegetation reliable values could be calculated (3200 kg/ha for *Avenetum* and 1400 kg/ha for *Festucetum*). Values for grazed vegetation were somewhat irregular (cf. 3.2.1).

For these generalized calculations of stocking rate the figures are rounded off to be 2000 kg/ha for grazed *Avenetum* whereas that for grazed *Festucetum* will be decreased to 1100 kg/ha, which is more realistic than the figure obtained. Values from the productivity estimations in Chapter 5 have not been used as they were obtained only from the *Avenetum* and only during one season. Furthermore, they do not contradict the values used.

From these figures a rough calculation of a suitable stocking rate on the Alvar, desirable from a nature conservation point of view, could be made.

The percent used of the available herbage during a season is calculated to 50% for this type of vegetation (Steen et al. 1972 p. 24). It is considered to be the same for sheep and heifers. A calculation of stocking rate for a grazing season of 180 days can be made as in Tables 53 and 54.

The distribution of these two main plant communities varies from place to place. As they are related to various soil types, *Avenetum* to gravelly deposits and *Festucetum* to weathered soils, their covers have been calculated from a physiognomic map of the Alvar to 26% for gravelly deposits and 54% for weathered soils (Königsson 1968, Map enclosure; Enckell et al. 1979). However, these figures include transitional zones as well, with very thin soil layer and low production, see Fig. 31 (Königsson pers. comm.). More realistic figures corresponding to sites where the present production plots were located are 15% and 25% respectively.

Thus, for an ungrazed average type of alvar, 15% (*Avenetum*) of 3520 (Mcal/ha) and 25% (*Festucetum*) of 1260 (Mcal/ha) gives 843 (Mcal/ha). For a grazed average type of alvar the same calculation provides 593 (Mcal/ha).

The type of sheep used on the Alvar is the Swedish landrace (fur type). A ewe maintains a weight of about 55 kg and a lamb reaches about 40 kg within the grazing season.

A ewe without lambs needs 2—2.1 Mcal per day for maintenance and fleece production. If she has a lamb and provides milk there is a need of 2.8 Mcal per day, thus needing 504 Mcal for a grazing season of 180 days. A single lamb grows about 150 g per day which means 1.7 Mcal per day and 306 Mcal for the season (Steen et al. 1972 pp. 26 ff.; Sjödin 1980 pp. 139 ff.). Reports from sheep farmers on Öland indicate that a ewe produced an average of about 1.3 lamb on the Alvar. The energy need for 1 ewe + 1.3 lambs is 5.0 Mcal per day and 900 Mcal for the season.

Areas not grazed by sheep are very often extensively grazed by heifers. A 1.5 years old heifer has a weight of about 350 kg. The growth per day is about 500 g, requiring 13.3 Mcal/day or 2394 Mcal per season (Helmenius 1977 p. 114).

Table 54 illustrates combinations of sheep or heifers per hectare during a season. The calculations assume that no supplementary feeding takes place during that time.

A recommended stocking rate in the first year on an area that has not previously been grazed for a long period is about 0.9 of the combination 1 ewe and 1.3 lambs, or about 0.4 heifers per hectare. If grazing is maintained for an uninterrupted period of years the area probably will manage to provide feed for only 0.7 of the sheep equivalent or about 0.3 heifers.

These figures are somewhat higher than the pre-

Fig. 31. Large areas in the Stora Alvaret have very thin weathering soils. On these places only small amounts of herbage are produced. The plant cover often occurs in strips, indicating fissures in the bedrock, which enable moisture in the soil to be retained better. — Alvar of Stenåsa. August 1975.

Table 53. Calculated available amount of energy (Mcal) per hectare and season (180 days) for ungrazed (UG) and grazed (G) Avenetum and Festucetum respectively, with 100 % of cover and a calculated use by the animals of 50 %.

	Avenetum		Festucetum	
	UG	G	UG	G
Available herbage (kg dry wt/ha)	3 200	2 000	1 400	1 100
Energy content (Mcal/kg)	2.2	2.3	1.8	1.8
Available energy (Mcal/ha)	3 520	2 300	1 260	990

Table 54. Calculated combinations of animals per hectare on average types of alvar (ungrazed and grazed) during one season (180 days). - (1 heifer = about 2.7 of the combination 1 ewe + 1.3 lambs.)

	Combination	Need Mcal season	Ungrazed alvar (843 Mcal/ha) animals/ha	Grazed alvar (593 Mcal/ha) animals/ha
Sheep	1 ewe + 1.0 lamb	810	1.04	0.73
	1 ewe + 1.3 lambs	900	0.94	0.66
	1 ewe + 1.5 lambs	972	0.87	0.61
	1 ewe	504	1.67	1.18
	1 lamb	306	2.75	1.94
Heifer	1 heifer	2394	0.35	0.25

liminary values presented for sheep in Rosén (1974 and 1980a pp. 328 ff). However, it must be remembered that values of stocking rate as calculated above are generalized values for an average type of alvar. An adjustment has to be made to separate parts of the Alvar due to the widely varied structure of plant communities. Obviously the very thin gravelly deposits and weathered soils also support small amounts of herbage (not involved in this calculation) as also do the fens and wet meadows (18%), the latter however are not preferentially grazed. During drought periods some of these meadows may be grazed instead of vegetation in the *Festucetum* and the *Avenetum,* which dries-up more rapidly—the animals naturally select green vegetation in preference to dry (cf. 7.1.4).

Production of herbage and energy is closely related to the type of plant community and its composition. Other realities which ought to be considered are, e.g., selectivity in grazing, range behaviour, climatic fluctuations, kind of animals, intensity of grazing and response of plants to grazing. Although not involved in calculations such variables are discussed in the present paper.

An approach to include such interactions between plant growth and animal production in calculations is suggested, for example, in a model by Noy-Meir (1978 pp. 809 ff.).

9 General discussion

The limestone grassland on Öland, the so-called Stora Alvaret, has a very mosaic vegetation, made up of several plant communities, most of which are considered as xerophilous. This alvar vegetation, maintained by a combination of edaphic and climatic conditions, also contains several taxa which are not found on the Swedish mainland. Climatic factors, as low precipitation in combination with high insolation, favour various adaptations of plants. Dwarf growth is frequent. Several taxa compensate for low precipitation by absorption of dew or mist water (Arvidsson 1951).

Knowledge of the cultural history of the Alvar is most important for the understanding of the actual and eventual structure of its vegetation. From a period of high impact of man by keeping grazing animals during the 19th century, it has been less grazed during this century. As a consequence, a process of overgrowing started, mostly by junipers. This process was abruptly checked in widely spread areas by the intensive sheep farming which started in the late 1950's. Far-reaching changes of vegetation appeared. Nature conservancy aspects induced the start of the present investigation in 1969. Relations between vegetation and grazing animals were to be studied as well as production of above-ground biomass.

Experiences of biomass research were fairly few at the time of the start of the investigations which caused some problems in their design. Permanent plots were established in two preferentially grazed plant communities, the *Avenetum* (*A.*) and the *Festucetum* (*F.*). After one year's harvest the plots were separated into four subplots giving possibility for a study of increased effect of the harvesting treatment, i.e., the "wear", and the subsequent recovery (cf. Chapter 3). The use of various sizes of permanent plots was, of course, expected to create uncertain conditions for comparison due to the possible increases of border effects. However, the change of size did not show any remarkable changes in, e.g., number of species or cover degrees. From a statistical point of view a larger number of plots would have been desirable, but would not have been possible for one man to handle.

Values of standing crop were calculated as mean values of two years, giving 320 g/m^2 for *Avenetum* and 140 g/m^2 for *Festucetum,* both ungrazed. For grazed, 192 g/m^2 (*A.*) and 147 g/m^2 (*F.*) were obtained, of which the latter may be slightly too high (cf. 3.2.1).

Decreasing standing crops caused by the harvest treatment was most pronounced for *F.* More pronounced decreases occurred in ungrazed *A.* plots than in grazed ones, the latter probably being adapted to wear by grazing.

An increased part of the biomass total for the year is found in the autumns following repeated harvests. When reaching a stabilized state the proportions are about 75% (summer) and 25% (autumn) for all kinds of *A.*, and for *F.* about 50% to 50% (except for ungrazed *F.*). Harvested *A.* plots, which were left to recover for two years before a new harvest, reached initial values, which was not the case for the *F.* The latter is more sensitive to wear by cutting (or heavy grazing) than the *A.*, as the grass tufts are easily damaged. This damage is worsened by frost-induced soil movements, which are most frequent in loose tuft vegetation.

The three different components (graminids, herbids, and dwarf shrubs) in *F.* showed a trend of decreasing yields with increasing wear in the summer. In the autumn it increased but with different figures for grazed and ungrazed. In the *A.*, only graminids showed a weak decreasing trend in the summer.

Considering the proportions of these three categories, there is a decrease with increasing number of harvests in both *A.* and *F.* for graminids and for dwarf shrubs (more or less) but an increase for herbids.

For example, in ungrazed *A.*, graminids de-

crease from 61% to 29% and dwarf shrubs from 11% to 3% while herbids increase from 28% to 68%. In grazed *A.*, the amplitudes of change are smaller. Thus grazing changes the composition of the vegetation considerably. Continued wear (by harvests) cause very similar proportions of components, both in grazed and ungrazed plots.

Low values of standing crop were obtained for graminids in the *A.* (1970), as also shown with much lower cover values than 1969 in the control plots, being most pronounced for *Festuca ovina*. This was most probably a consequence of the drought period in 1969. It has been observed that annuals tend to increase after such dry periods. *Filipendula vulgaris* showed its strong competitive ability after the drought in 1969 as frequently increasing in cover.

Records of 11 years of fluctuations in cover for various taxa were obtained from control plots, the most pronounced fluctuations being for *Festuca ovina*. The latter decreased in 1970 and then, competing mainly with herbids, needed 8—10 years to obtain cover values of the same level as in 1969.

Changed proportions of plant groups were found, but only small changes in number of taxa for grazed and ungrazed plots. The far-reaching substitution of taxa showed by Ljung (1970) in folds was not found in this material, as my plots were located at some distance from sheep-barns and feeding places.

Records of taxa demonstrated that a few species from ungrazed *Avenetum* were dominant with high cover values, e.g., *Festuca ovina, Arrhenatherum pratense,* and *Filipendula vulgaris*. Several taxa shared the dominance in grazed plots, but with lower cover values, e.g., *Festuca ovina, Plantago lanceolata, Galium verum, Veronica spicata,* and *Achillea millefolium*. This shared dominance in grazed plots (areas) is considered to be the reason for a more stabilized situation due to wear than in ungrazed plots. For the *Festucetum,* differences between ungrazed and grazed plots are not that pronounced, but the occurrence of annuals increases in the latter.

In the bottom layer, the lichens are fragmented by trampling and thus decrease in size and cover in grazed plots. Bryophytes and lichens also adapted to wear, although this was not so noticeable as the adaptation was hidden by a recovery process after drought. The increase of acrocarpous mosses, such as *Bryum, Pohlia,* and *Ceratodon,* was favoured due to the wear. *Bryum* species colonized most frequently, a colonization that also took place in heavily sheep-grazed areas. After grazing or harvest, several acrocarpous mosses of low competitive ability colonize on bare soil, probably creating a poorer situation for the recovery of the field layer and thus resulting in a lower production of that layer.

The fertilizing experiment showed an increase of production reaching more than 200% in fertilized *Avenetum* vegetation, for example, 126 g/m^2 (totally) was obtained for control plots in 1972, but 411 g/m^2 for highest fertilizer treatment. However, there was a change in the composition of the vegetation, caused by the increase of graminids, mostly *Festuca ovina,* while herbids and dwarf shrubs decreased. This is not acceptable from a conservancy point of view. The number of taxa will also decrease after some time (cf. Willems 1980) although not recorded in this experiment. Naturally, neither is this change acceptable from a conservancy viewpoint. Analyses of soil and energy were also made to complement the information. The total energy content in the vegetation increased with a larger amount of fertilizer, but per unit weight there was a weak decrease. The energy values in August and November may be too low to reflect the entire season due to seasonal variations. The soil analyses showed increased amounts of K (available), P (stored), org. C, and tot.-N.

If compared with results of the soil samples taken in some sheep-grazed areas, the fertilizing experiment showed much lower values. As no analyses of standing crop were made of N, P or K it is impossible to state which had the highest influence.

Climatic factors, especially the precipitation, have been closely studied as they are most important in regulating dynamics of the Alvar vegetation. Drought periods occur frequently in June—July, decreasing the production in the Alvar. The standing crop in the *Avenetum* was investigated monthly from May to October in 1972. Two pronounced maxima were found in the amounts of living and total standing crop during that season, as well as for graminids and dwarf shrubs. Herbids showed only one maximum in late

June—early July. However, the method used was not applicable to measure that kind of production, which apparently also occurs during a dry period. By estimating the probable levels of production during the periods when the living mass of these groups decreased, an estimation of the productivity for the grazing period could also be made. The value obtained, 248 g/m^2 (for 160 days), might be a better estimation of the production than only adding the positive increases for the living crop (168 g/m^2). However, production also takes place in spring and late autumn but this is not included in the calculations. The variations in standing crop during a grazing season indicate that there might be a lack of feed in an optimally grazed area during a period of drought. Animals prefer green vegetation to dry and, besides, also show preferences among the green taxa. This selectivity in grazing accentuates the effect of drought by limiting the available crop for grazing even more. Thus extra feed ought to be supplied, or the number of animals decreased, during and after the drought period to avoid overgrazing (locally) and damage.

Many uncertainties are involved in estimations of primary production (above-ground), calculated either from individual taxa or groups. Turnover rates for involved taxa were shown by Williamson (1976) to give a considerable increase in the production figures from a chalk grassland if included in the calculations; the figures for living crop were more than doubled over the year.

The impact on the vegetation by sheep grazing, if heavy, results in the killing of most of the low shrubs in the area. Original alvar species are replaced due to a combined effect of wear, trampling, and manuring, which strongly support anthropochorous taxa in colonizing and surviving. The manuring and defoliating by grazing may increase the production (cf. Chapter 4 and 7.1.4). In contrast, the invasion of acrocarpous bryophytes and/or the increase in frequency of bare soil patches have negative effects on the production. Changes in composition of the vegetation have been found to include a higher percentage of herbids with prostrate growth forms.

An opening of the landscape giving less shrubs and a lower sward will provide an increased effect of evaporation from the soil by allowing strong winds to come closer to the surface. Dew will dry off faster and the soil temperature will increase. The individual species in the vegetation receive less shelter against the permanent winds. In addition, I have found a lower mean snow depth in the short-grazed vegetation, as well as in shrubless or cleared areas. This provides a shorter period of shelter in spring, thus exposing the vegetation to a longer influence by insolation and winds. The windspeed has a negative influence on the growth of graminids (cf. 2.2.5). This must be regarded only as one part of the interference, but in combination with the above-mentioned impacts it will decrease the productivity in a sheep-grazed area and make the presence of extremely prostrate growth forms more pronounced among herbids.

There is no doubt that grazing animals play an important role in the longterm development and the stabilization of the Alvar vegetation. Changes in kinds of animals, decreased grazing intensity, and the ceased clearing by man have allowed heavy overgrowth to start in large areas on deeper soils. Especially the decreased number of sheep (in some areas) and disappearance of horses have favoured junipers and allow them to establish a scrub when no longer grazed. From a cleared testplot, a standing crop of 3 248 kg/ha (dry weight) was obtained for junipers, of which 41% was made up of assimilating parts. The stand has a mean age of 49 years, calculated from 136 junipers (of totally 201). The small junipers and seedlings not included in the age determinations made up only a very small part of the standing crop.

This process of scrub formation has been mapped in detail and measured in the permanent plots of junipers. The ability to establish new seedlings in open areas between old junipers, but not close to them is increasing the rate of scrub formation. Young junipers show a much higher growth rate than old ones. Figures from the control plot revealed a 45% increase in cover for the total stand of junipers within 10 years, which may be considered as a fast process.

A large number of juniper seedlings established and survived within the period of 10 years, being most pronounced in the cleared area. Released nutrients and decreased competition probably favoured the establishment. The decreased speed of establishment of seedlings from 1976 to 1981 may

be caused by the increasing sward in the plots, as they are no longer grazed.

The age distribution of the junipers may reflect suitable years for seedlings in the past, but also the impact of man by grazing and woodcutting. The few old shrubs in the population, most probably reflect such influence, as there is no reason why the old ones could not have been more frequent.

An area of scrub, becoming denser, also favours the microclimate by increased windshelter and rising temperature. More water will be supplied in spring as the junipers gather snowdrifts on their leeward sides. A mean value (5 years) showed a 56% deeper snow cover in the uncleared area than in the cleared. Shrubs such as *Prunus spinosa* and *Rosa* spp. often colonize within juniper shrubs. An acidification of soils is caused by junipers, often giving the lowest pH values at a depth of 5—15 cm.

If a juniper shrub is cleared, the remaining needle area on the ground requires a fairly long time to become totally covered by colonizing plants. As a consequence of the increased insolation after clearing, such areas loose their bryophytes with low drought tolerance, frequently growing under the shrubs with high cover degree.

Filipendula vulgaris and *Arrhenatherum pratense* were among the first colonizers, then followed by taxa such as *Poa compressa, Cirsium acaule,* and *Fragaria viridis.* After a period of 5—7 years all areas were covered by plants, totally or at least to 75%. If a combination of thinning and grazing is planned for opening up a juniper scrub the grazing intensity must be limited and increased step by step to avoid soil erosion becoming initiated from such needle areas.

To maintain a balanced grazing pressure in the Alvar there are many factors that must be taken into account. Information about the percentage distribution of various plant communities within the area, their production and mean energy content during the grazing season, as well as kind of animals and their energy requirement per day is needed. Less easy to distinguish are, for example, the grazing selectivity and range behaviour of the animals and also the decrease of the above-ground production due to years of exceptional drought.

Energy contents in the preferentially grazed plant communities were calculated from monthly harvests and given as mean values for the season. Naturally, this is best when done for various years, but was not possible in this investigation. However, by means of the figures obtained a recommended stocking rate for an average alvar was calculated (cf. 8.1.3). For the first year of grazing in an area of the Alvar formerly ungrazed for a long period, 0.9 of the combination 1 ewe and 1.3 lambs or 0.4 heifers per hectare was obtained for a grazing period of 180 days. If grazing is maintained for a longer period of years, an equivalent of 0.7 sheep or 0.3 heifers may be recommended.

As mentioned in 8.1.3, some areas in the Alvar have not been included in the production figures as they are not preferentially grazed, i.e., the fens and wet meadows and areas with very thin soil layers. The former may provide additional herbage during dry periods, when selectivity is decreased.

However, the grazing intensity must be adapted to the individual areas where grazing is planned to take place. In due course, available biomass of grazing areas may be estimated more rapidly using a combination of harvests and spectral reflectance measurements (cf. Tucker & Rosén MS), aiming gradually to minimize the time-consuming harvest work in the future.

It has been demonstrated, e.g., by Jones (1967 pp. 46 ff.) that rotational grazing may increase the production. On the Alvar such a grazing regime has been used in some areas, providing good weight gains for the sheep.

As regards mixed grazing, Brelin et al. (1978) and Brelin (1979, 1980) have demonstrated that grazing with sheep and cattle together improves the gain in meat production compared to the gain obtained when each species grazed separately. The gain for the sheep is highest, with weight gains of about 20%.

Various conditions, such as better utilization of available vegetation, a better regrowth due to the even sward as a result of grazing, and lower burden of gastro-intestinal parasites are said to give results of that kind. Consequently, the best use of the Alvar ought to be obtained in a combination of rotational, balanced and mixed grazing.

If grazing intensity is too high there is a risk that taxa with low grazing tolerance may be eliminated.

With scattered, sporadic grazing or even with a weak permanent grazing the rate of the overgrowing process continuously increases, which will also decrease the number of taxa and change the structure of the vegetation.

The alvar vegetation may be considered to have a high priority in a global perspective of conservation. Its area is very limited and is now decreasing not only on Öland but also in the other main area in Estonia (cf. Laasimer 1981; Kalda 1981). This underlines the importance of fulfilling the intentions to establish Nature Reserves in the Alvar, but also of deciding the policy for the entire area. Management rules must be created for grazing, thinnings, etc., in order to maintain the typically high species diversity and the unchanged structure of endemic plant communities in the Stora Alvaret.

ACKNOWLEDGEMENT

This investigation was possible due to financial support from the Swedish National Protection Board, and by support in various ways from the Institute of Ecological Botany, Uppsala University.

During the periods of field investigations I had my base at the Uppsala University Ecological Station in Ölands Skogsby. I am grateful to the director, Bertil Kullenberg, and his staff.

Assistance with cuttings and others was given by Sonja Nilsson and her family, Christina Rosén, Eva Dahlström, Elisabeth Ljung, Kristina Andersson, and Lage Johansson. Information of various kinds was given by my colleagues in the project, Elisabeth Ljung and Claes Swendsén.

Regina Iwanicka, Maud Wallsten and several of the staff of the Institute of Ecological Botany have assisted in laboratory work.

Advice on analyses of soils and plant material was given by Eliel Steen, Department of Ecology and Environmental Research, Swedish University of Agricultural Sciences.

Valuable suggestions and criticism on the manuscript were given by Hugo Sjörs and Eddy van der Maarel, Institute of Ecological Botany. Detailed information on Quaternary Geology was given by Lars König Königsson, Department of Quarternary Geology, Uppsala University.

Märta Ekdahl and Aina Vallin have typed the MS and Folke Hellström assisted with the black and white photos; Agneta Nordgren did the drawings. Åke Sjödin provided information on the literature, Kuno Thomasson assisted with the references, and Birgitta Gustafsson with corrections of the MS. Nigel Rollison helped me with the linguistic revision.

Financial support from the Axel and Margaret Ax:son Johnson Foundation enabled the colour plates to be included.

To all the institutes and people mentioned above, as well as to all other friends and colleagues who have supported me with advice or spontaneous assistance, I wish to express my sincere thanks.

Particularly, I wish to record my appreciation for the help provided by my supervisor and project manager Erik Sjögren, and also for his never-failing interest in my part of the investigation. I am most grateful to Erik Sjögren for scientific editing of the MS, and to Gunnel Sjörs for the technical editing.

Uppsala April 1982
Ejvind Rosén

Appendix 1. Cutting and separation of standing crop in summer and autumn (1972) accomplished in each of the Avenetum and Festucetum sample plots. Harvests in summer (Sum.) and autumn (Aut.). (G = grazed, UG = ungrazed, F = fenced, UF = unfenced, C = cut, NE = not existing).

		AVENETUM							
Subplot		BI		AIII		AII		AIV	
No. of years cut		1		2		3		4	
Season		Sum.	Aut.	Sum.	Aut.	Sum.	Aut.	Sum.	Aut.
G F	Plot no.								
	3	CS	CS	CS	CS	CS	CS	CS	CS
	6	CS	CS	CS	CS	CS	CS	CS	CS
	7A	NE	NE	C	-	CS	--	CS	--
	7AA	NE	NE	CS	CS	CS	CS	CS	CS
	28	CS	CS	--	--	-	--	CS	CS
	30	--	--	--	--	--	--	--	--
	Total	3 C	3 C	4 C	3 C	4 C	3 C	5 C	4 C
		3 S	3 S	3 S	3 S	4 S	3 S	5 S	4 S
G UF	Plot no.								
	4	CS	--	CS	--	CS	pp	CS	--
	5	CS	CS	CS	CS	CS	CS	CS	CS
	8A	NE	NE	--	--	--	--	--	--
	8AA	NE	NE	CS	CS	CS	CS	CS	CS
	27	--	--	--	--	--	--	--	--
	29	CS	CS	--	--	--	--	CS	CS
	Total	3 C	2 C	3 C	2 C	3 C	2 C	4 C	3 C
		3 S	2 S	3 S	2 S	3 S	2 S	4 S	3 S
UG F	Plot no.								
	13	C	C	CS	C	C	C	C	C
	14	C	--	C	--	C	--	C	--
	15	CS	CS	CS	CS	CS	CS	CS	CS
	16	CS	CS	CS	CS	CS	CS	CS	CS
	17	C	--	C	--	C	--	C	--
	18	C	--	C	--	C	--	C	--
	35	CS	CS	CS	CS	CS	CS	CS	CS
	36	--	--	--	--	--	--	--	--
	37	CS	CS	--	--	--	--	CS	CS
	38	--	--	--	--	--	--	--	--
	39	--	--	--	--	--	--	--	--
	40	C	C	C	C	CS	C	C	C
	51	C	--	C	--	C	--	C	--
	52	CS	CS	CS	CS	CS	CS	CS	CS
	53	C	--	C	--	C	--	C	--
	54	--	--	--	--	--	--	--	--
	57	--	--	--	--	--	--	--	--
	58	--	--	--	--	--	--	--	--
	59	CS	CS	CS	CS	CS	CS	CS	CS
	60	--	--	--	--	--	--	--	--
	Total	13 C	8 C	12 C	7 C	12 C	7 C	13 C	8 C
		6 S	6 S	6 S	5 S	6 S	5 S	6 S	6 S

		FESTUCETUM							
Subplot		BI		AIII		AII		AIV	
No. of years cut		1		2		3		4	
Season		Sum.	Aut.	Sum.	Aut.	Sum.	Aut.	Sum.	Aut.
G F	Plot no.								
	1 A	NE	NE	CS	CS	CS	CS	CS	CS
	1AA	NE	NE	CS	CS	CS	CS	CS	CS
	23	CS	--	CS	--	CS	--	CS	--
	26	CS	CS	CS	CS	CS	CS	CS	CS
	31	CS	CS	CS	CS	CS	CS	CS	CS
	33	CS	CS	CS	CS	CS	CS	CS	CS
	Total	4 C	3 C	6 C	5 C	6 C	5 C	6 C	5 C
		4 S	3 S	6 S	5 S	6 S	5 S	6 S	5 S
G UF	2A	NE	NE	CS	CS	CS	CS	CS	CS
	2AA	NE	NE	CS	--	CS	--	CS	--
	24	CS	--	CS	--	CS	--	CS	--
	25	CS	CS	CS	CS	CS	CS	CS	CS
	32	CS	CS	CS	CS	CS	CS	CS	CS
	34	CS	CS	CS	CS	CS	CS	CS	CS
	Total	4 C	3 C	6 C	4 C	6 C	4 C	6 C	4 C
		4 S	3 S	6 S	4 S	6 S	4 S	6 S	4 S
UG F	9	CS	CS	CS	CS	CS	CS	CS	CS
	10	C	C	C	C	C	C	C	C
	11	C	C	C	C	C	C	C	C
	12	C	C	C	C	C	C	C	C
	19	C	--	C	--	CS	--	CS	--
	20	C	--	C	--	CS	--	CS	--
	21	CS	--	CS	--	CS	--	CS	--
	22	CS	CS	CS	CS	CS	CS	CS	CS
	41	CS	CS	CS	CS	CS	CS	CS	CS
	42	--	--	--	--	--	--	--	--
	43	CS	C	CS	C	CS	C	CS	C
	44	CS	CS	CS	CS	CS	CS	CS	CS
	45	CS	C	CS	C	CS	C	CS	C
	46	CS	CS	CS	CS	CS	CS	CS	CS
	47	CS	CS	CS	CS	CS	CS	CS	CS
	48	C	--	C	--	CS	--	CS	--
	49	CS	--	CS	--	CS	--	CS	--
	50	CS	CS	CS	CS	CS	CS	CS	CS
	55	CS	--	CS	--	CS	--	CS	--
	56	CS	CS	CS	CS	CS	CS	CS	CS
	Total	19 C	13 C	19 C	13 C	19 C	13 C	19 C	13 C
		13 S	8 S	13 S	8 S	16 S	8 S	16 S	8 S

Plate 1:1. Zonation of plant communities from exposed bedrock to areas with gravelly deposits. Lichen communities are followed by "*Sedetum tortellosum*", and then on shallow soils by the *Festucetum*. The *Avenetum* with junipers is found where still deeper soils are available. — Alvar of Nedre Ålebäck. 2 July 1972.

Plate 1:2. Fluctuations in cover of taxa from year to year sometimes are very pronounced, as for *Anthyllis vulneraria* in 1971 when it was dominant in several plant communities where it normally occurs rarely. — Alvar of Nedre Ålebäck. 3 July 1971.

Plate 1:3. Grazing animals prefer green parts of the vegetation. On the Alvar it has been noticed that the *Sesleria* community with a high dominance of fairly stiff taxa, such as *Carex flacca* and *Sesleria coerulea* ssp. *uliginosa*, is not frequently grazed. However, in the dry summer of 1975 heavy grazing was noticed in that community in several parts of the Alvar. In spite of the stiff taxa the animals obviously sought green and fresh material which could be found almost only in shallow depressions. Dry parts of the community were less grazed. —Alvar of Karlevi. 17 August 1975.

Plate 2:1—4. Effects upon the vegetation (1970—73) in test plot 59 A, ungrazed fenced *Avenetum*, caused by harvests in 1969—72 (cf. Fig. 8). — 1. (23 July 1970) The effects of harvest were combined with the drought in 1969. Herbids dominated. — 2. (7 July 1971) Herbids still dominant. *Plantago lanceolata* has increased in cover. — 3. (13 July 1972) A pronounced difference has developed between the longest harvested subplot (bottom left) compared with the other subplots. — 4. (14 July 1973) Recolonization by graminids, however, is fairly small compared with subplot A I (above right). Further detailed information in text and in Table 15. — Alvar of Nedre Ålebäck.

Plate 2:5—8. Effects upon the vegetation (1970—73) in test plot 26 A, grazed fenced *Festucetum* caused by harvest in 1969—72 (cf. Fig. 8). — 5. (25 July 1970) The vegetation in the test plot has become sparse. Its former structure with scattered tufts of *Festuca ovina* is almost lost. — 6. (6 July 1971) The cover has still further decreased; frost-induced soil movements have increased. — 7. (12 July 1972) Very little is left of the original structure of the vegetation. — 8. (11 July 1973) Situation almost unchanged to that in 1972. *Linaria vulgaris* is slightly more frequent than earlier. Further detailed information in text and in Table 18. — Alvar of Stenåsa.

Plate 3:1—4. Recolonization of phanerogams in the needle area of the cut juniper shrub no. 6. — 1. (26 Oct. 1970) The shrub was placed in class III (with a diameter of 2—3 m, cf. 6.1) and cut in early November. — 2. (8 Oct. 1971) Very little had happened in the area. — 3. (16 Aug. 1972) A small colonization most frequently took place from the border. — 4. (11 Aug. 1975) More than half the area is covered by plants. Graminids have now increased their share. Colonization in central parts of the needle area has increased. Further detailed information in text and in Table 46. — Alvar of Nedre Ålebäck.

Plate 3:5. On weathering soils *Helianthemum oelandicum* becomes very dominant in some alvar areas, giving another physiognomy to the plant cover than the *Festuca ovina* tufts. The resistance of *H. oelandicum* to frost-induced soil movements is high, the species then being frequent in such habitats. — Alvar of Skärlöv. 14 June 1971.

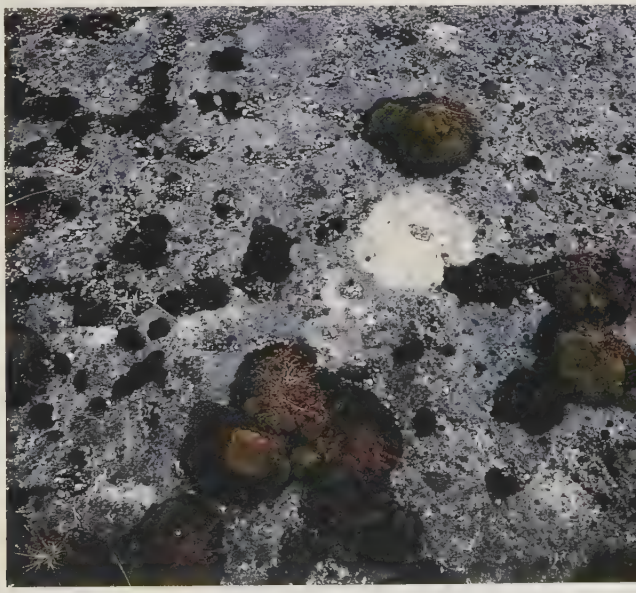

Plate 3:6. The "*Sedetum tortellosum*" association is found on exposed bedrock with small amounts of soil. *Tortella tortuosa, T. inclinata,* and *Schistidium apocarpum* form moss cushions, which however are easily damaged or moved by trampling. *Sedum album* is a frequent colonizer in these cushions. — Alvar of Nedre Ålebäck. May 1974.

Plate 4:1. Heavy grazing changes original plant communities considerably, most pronounced in areas where sheep gather, as in folds and close to sheep-barns. Original taxa may be totally replaced by anthropochorous ones. Fold where sheep stayed during winter. — Alvar of Karlevi. November 1969.

Plate 4:2. The far-reaching transformation of original plant communities is pronounced, especially along fences surrounding sheep grazed areas. Several taxa are less frequent or even extinct in the grazed area than outside. In one alvar area, *Bromus hordeaceus* became highly dominant but was very little grazed as it dried up very early in the summer. *Sedum reflexum* and *Galium verum* are dominant outside the fence. — Alvar of Kleva. 14 July 1970.

Plate 4:3. In an *Avenetum* area with junipers, very heavy grazing will cause the junipers to die and will change the composition of the plant cover, leading to a larger share of herbids than graminids. In such an area *Urtica dioeca* frequently invaded places where junipers had been eliminated. Several other anthropochorous taxa were also involved in the change. — Alvar of Kastlösa. September 1970. Photo E. Sjögren.

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